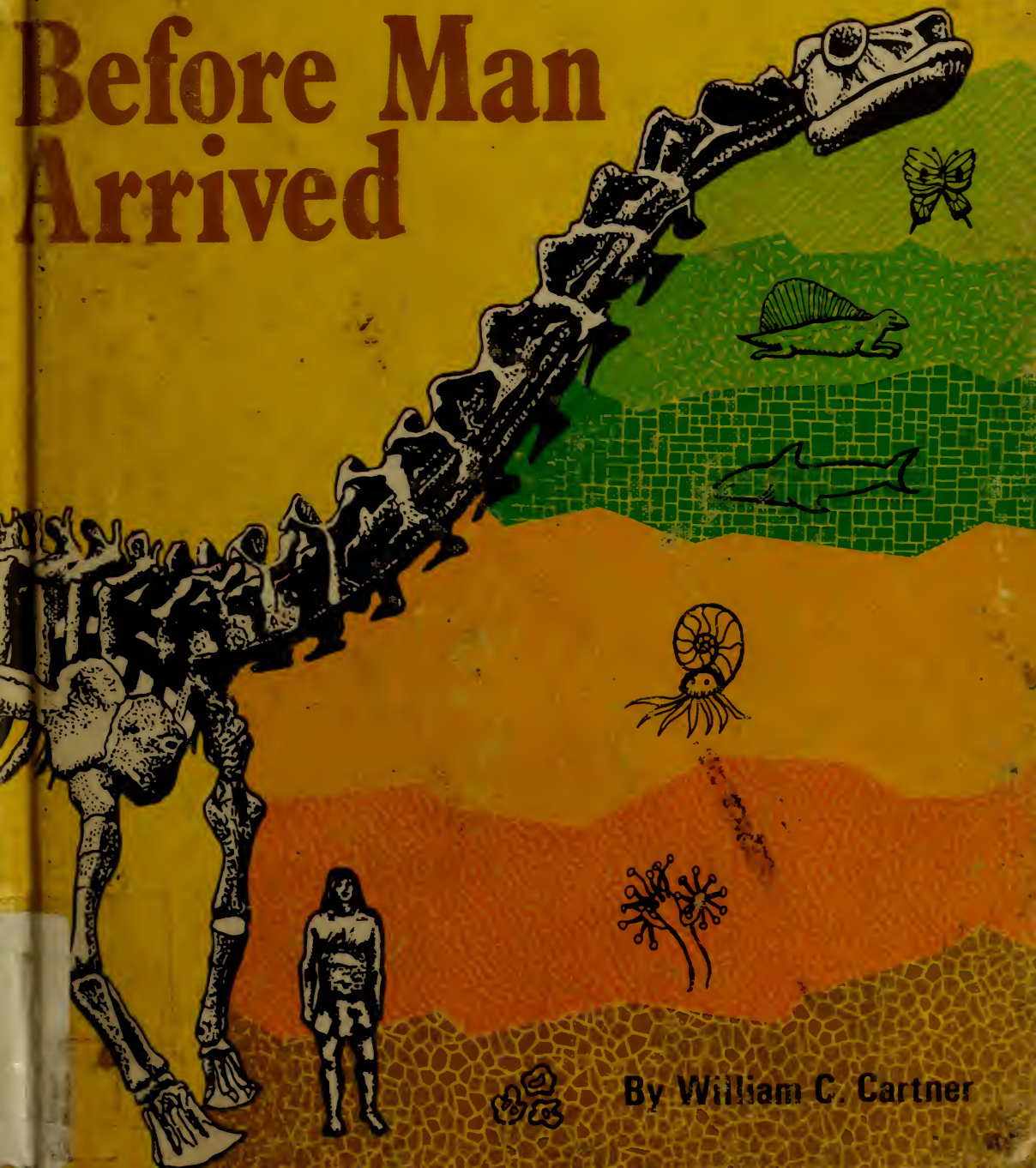
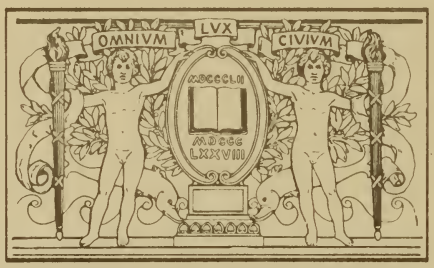
HOW WE KNOW

What on Earth Happened Before Man Arrived



By William C. Cartner



BOSTON
PUBLIC
LIBRARY

HOW WE KNOW

What on Earth Happened Before Man Arrived

By William C. Cartner

STERLING PUBLISHING CO., INC. NEW YORK

ACKNOWLEDGMENTS

For some of the material used in this book the author gratefully makes acknowledgments to: The Director and Staff, Teesside Museums Service; Shell International Petroleum Company Limited; The Northern Echo; The British Young Naturalists Association, Director G. G. Watson, Esq.; J. Young, Esq., The Hancock Museum, Newcastle upon Tyne; H. R. Rackerby, Esq., Lingdale School, Yorkshire; Whitby Museum; The Trustees of the British Museum; The Controller of Her Majesty's Stationery Office for the Crown Copyright photographs.

The publishers would also like to thank the following for pictures reproduced in this book: Canadian National Railways (photo, p. 87); Frank M. Carpenter Biological Laboratories (photo, p. 16); Pittsburgh Photographic Library, University of Pittsburgh (photo, p. 48—photo by Hare); Standard Oil Co. of New Jersey (photos, p. 6, 18, 43, 77, 82, 89, 91); Sterling Junior Pictorial Encyclopedia of Science (Sterling Publishing Co., Inc.) (photo, p. 51).

Part III of this edition, researched by Rhea Rollman, M. M. Furia, and Edward W. Egan.

American Edition © 1972 by Sterling Publishing Co., Inc.
419 Park Avenue South, New York, New York 10016
Originally published under the title "Fun with Palaeontology"
Copyright © 1970 by Kaye & Ward Ltd., London
Manufactured in the United States of America
All rights reserved
Library of Congress Catalog Card No.: 76-180466
ISBN 0-8069-3046-2
3047-0

CONTENTS

GLOSSARY 5

PART I: HOW WE KNOW 10

Ancient Lands and Seas . . . 10 . . . The Fossil Record . . . 12 . . . Recognizing Fossils . . . 14 . . . The Paleozoic Rock Systems . . . 17 . . . Trilobites and Graptolites: Index-Fossils . . . 19 . . . The Mesozoic Rock Systems . . . 21 . . . Mineral Replacement . . . 24 . . . The Cenozoic Rock Systems . . . 26 . . . A Living Fossil and Where It Fits . . . 28 . . . A Living Fossil-Link? . . . 30 . . . Brachiopods . . . 31 . . . Mollusks . . . 33 . . . Cephalopods . . . 34 . . . The Echinoderms . . . 38 . . . Corals and the Like . . . 40 . . . Bryozoa . . . 41 . . . Stratigraphy . . . 42 . . . Oil . . . 43 . . . Plant Fossils . . . 45 . . . Amber and Jet . . . 47 . . . Dinosaurs . . . 48 . . . The End of a Race . . . 50 . . . A Girl Who Found a Fossil Reptile . . . 52 . . . The Earliest Bird . . . 54 . . . The Primates and Man . . . 56 . . . Evolution of the Primates . . . 56 . . . Evolution of Man . . . 57

PART II: HOW TO COLLECT 59

Marine Fossils . . . 59 . . . Erosion and Sedimentation . . . 59 . . . Field Work . . . 60 . . . Equipment . . . 60 . . . Field Sketching . . . 62 . . . Operation *Neptunea contraria* . . . 65 . . . Preparing Specimens . . . 65 . . . Photography . . . 68 . . . Microfossils . . . 70 . . . Museum Study . . . 72 . . . Your Fossil Club . . . 73 . . . Fossil Hunter or Paleontologist? . . . 74

PART III: WHERE TO FIND THEM 75

INDEX 94

Glossary

All scientific words are explained when they are first used in the text. This glossary is here so you can look up a definition you may have forgotten.

ANNELIDA: the phylum (see phylum in glossary) of the Animal Kingdom which includes the major types of worms. (Reign: pre-Paleozoic to the present.) The annelids form one of the oldest groups of animals in existence—much older than man. (From the Latin *anulus* meaning "ring" and referring to the fact that most worms in this phylum are segmented.)

ANTICLINE: the form taken by bedded rocks that have been pushed up in the shape of an arch or dome.

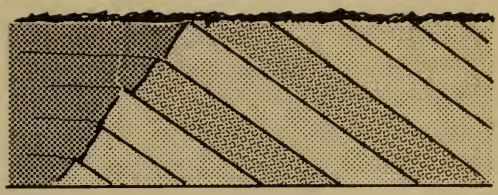
ARGILLACEOUS: rocks containing clay or composed of it. (From the Latin *argilla* meaning "clay.")

ARTHROPODA: the phylum that includes spiders, crabs, insects, ostracods, and the very important (to fossil hunters) extinct trilobites. (Reign: Cambrian to the present.) (From the Greek words meaning "jointed legs.")

BASALT: a hard black rock of volcanic origin. It does not contain fossils.

BRACHIOPODA: primitive animals living in bivalved shells. (Reign: pre-Paleozoic to the present.) (From the Greek words meaning "arm–leg" and implying mistakenly that the brachiopods use their arms for locomotion.)

BRYOZOA: a phylum of tiny, jellylike sea animals that live in colonies and secrete hard exoskeletons. (Reign: Cambrian or pre-Paleozoic to the present.) (From the Greek words meaning "moss animals" and sometimes called the "Polyzoa.")



Illus. 1 Bedded rock will often slope at an angle, thus forming a DIP.

CAST: sediment that has formed a positive likeness of some organism. To get a cast, you first need a mold. The mineral or soil fills the impression (mold) left by the hard part of a dead plant or animal. Then this gives you a perfect replica of what that ancient animal looked like, when the solidified sediment is carefully removed. When empty shells are filled internally, this can produce a cast of the inside of the shell.

CEPHALOPODA: the highest class of mollusks, comprising the cuttlefish (squids, octopuses and their like) plus some soft-bodied creatures that put forth shells (the nautiluses and extinct ammonoids). (Reign: Cambrian to the present.) (From the Greek words meaning "HEAD–foot.")

CHALK: a white rock formed from the fragments of ancient sea animals whose hard parts were calcium substances (lime). Chalk is extremely fossiliferous.

CHORDATA: phylum containing all creatures whose nervous systems are based on a central cord: the mammals, reptiles, fish, birds, and amphibians. (Reign: Cambrian to the present.) (From the Greek word meaning "catgut" and indicating something that substitutes for a string.)

CLAY: soft, pliable soil formed by erosion and sedimentation. It may contain fossils and often retains fossil *imprints*.

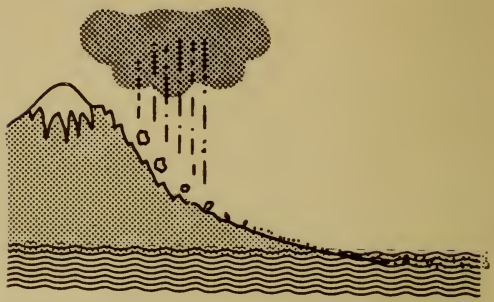
COELENTERATA: phylum of marine life containing all the corals, sea anemones, jellyfishes (rare as fossils), plus the Stromatopora (often referred to in Part III) and other Hydrozoa. This phylum contains the most famous of the reef-building animals, for most of these invertebrates secreted exoskeletons hard enough to form reefs that last to this day. (Reign: Cambrian to the present—although the Stromatopora, so sought after by fossil hunters—died out in Cretaceous times.) (From the Latin words meaning "hollow intestine" and referring to the fact that the soft inner parts of these creatures were unspecialized and dominated by a digesting cavity.)

CRUSTACEA: a subphylum of the Arthropoda and consisting of mostly aquatic arthropods. Crabs are the best-known representatives of this phylum, but it is the ostracods of Maryland and West Virginia which take prime importance paleontologically. (Reign: Cambrian to the present—although the ostracods did not appear until Ordovician times.) (From the Latin *crusta* meaning "hard shell.")

DIP: the angle or slope of bedded rock (see Illus. 1).

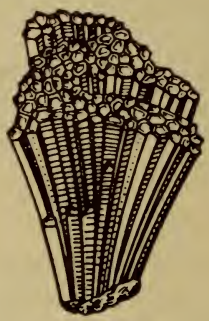
ECHINODERMA: interesting phylum of marine life containing both attached forms (sea lilies and the extinct blastoids) and free-moving creatures (sea urchins, starfishes, sea cucumbers and so on). (Reign: Cambrian to the present.) (From the Latin words meaning "spiny skin" and referring to their most noticeable characteristic.)

EROSION: wearing away of rocks and land surfaces by ice, rain and wind.



Illus. 2 Surfaces of whole states have been drastically changed by the process of erosion.

EXOSKELETON: a skeleton that is *outside* of the animal's body; an external, hard covering that soft-bodied animals secrete to protect themselves. Marine invertebrates are the most common possessors of exoskeletons.



Illus. 3 This preserved coral colony gives you a good idea of what an animal's exoskeleton looks like. But many exoskeletons are simply shells.

FAULT: a crack in the rock crust of the earth.

FLAGS: flat slabs of sandstone that split easily along the line of bedding.

FLINT: a very hard rock found as lumps in chalk.

FOLDING: a geological activity whereby ancient layered rocks that once lay

straight and level have formed folds (see Illus. 4) as a result of violent movements of the earth.

GASTROPODA: a class of mollusk having only single-valved shells or no shells at all. Best known among them are the snails, whelks, and limpets. (Reign: Cambrian to the present.) (From the Greek words meaning "leg–stomach" and describing these sea creatures' need to walk with their stomachs.)

Illus. 4 Folding will make ancient rock beds look like this.

GRANITE: a hard rock with large crystals, formed by great heat and slow cooling. It does not contain fossils.

IGNEOUS: rocks that were once hot, soft masses and have cooled and hardened. (Basalt, for instance, is a very common igneous rock.) (From the Latin *igneus,* meaning "formed by fire.")

INDEX-FOSSIL: a fossil that is so abundant in, or characteristic of, any particular period that you can date an entire geological area by finding one of these relics in its stratum or rocks. Naturally, the duration of the plant or animal species has to be brief, so most index-fossils had a rather limited time range. Belemnites, for instance, and the jawless fish of New Jersey and South Dakota are valuable index-fossils.

LIMESTONE: rock that is made up of lime or calcium carbonate. Often consisting of the shells of ancient sea creatures, it always originated as a sea bed and preserves marine fossils.

MAMMALIA: a class of vertebrates with spinal cords which took over the earth from the giant reptiles. They are characterized by warm blood (having a constant central heating system), offspring that are born live instead of being hatched from eggs, and the ability of their females to suckle the young. They include man, carnivores, primates, and various hoofed animals. Earliest were probably the shrews, hedgehogs, and sloths. (Reign: Triassic or Jurassic to the present.) (From the Latin word meaning "of the breast.")

MARBLE: a metamorphic (changed) form of limestone.

MATRIX: the especially thick rock rind surrounding a petrified or permineralized fossil or a fossil imprint.

METAMORPHIC: rock that has undergone a physical transformation. As dough is baked to become bread, so sedimentary rocks may be "baked" or changed by heat and pressure in the earth. Marble and slate are metamorphic rocks. (From the Greek roots meaning "a changed form.")

MOLD: The impression of an animal or plant left in the sediment in which it died. In this type of fossil, none of the original parts remain and no mineral replacement has taken place. Nevertheless we know what its outer surface looked like (from external molds) or else what its inner surface was like (from casts).

MOLLUSCA: the phylum that includes soft-

Illus. 5 Here limestone, a very fossiliferous rock, has taken the form of an anticline. Compare it with the diagram of a syncline in Illus. 6.

bodied, invertebrate sea animals (although many secrete hard shells). Does not include the brachiopods, however. Divided into many classes and subclasses, the Mollusca creatures are popularly called "mollusks." They include the extinct ammonoids and ammonites and belemnites. (Reign: Cambrian to the present.) (From the Latin word meaning "soft-bodied.")

OUTCROP: a rock surface clearly exposed at land level. Often it differs in age from the softer deposits surrounding it.

PELECYPODA: the class of mollusks comprising clams, mussels, oysters, and scallops. (Reign: Ordovician to the present.) (From the Greek words meaning "axe and legs" and describing the general shape of these mollusks' soft "feet.") Also called "Lamellibranchs."

PERMINERALIZATION: fossilization that takes place when minerals are added to the hard parts of an animal or plant (usually a shell) as opposed to mineral *replacement,* when pyrites, silica, calcite or some other mineral completely replaces the original structure.

PETRIFACTION: mineral infiltration of organic matter to the point where the organism does not decay, but instead turns into a stonelike substance with all its structures preserved—sometimes intact. Usually the infiltrating minerals are in solution. Petrified wood is the best-known example of this type of fossilization.

PHYLUM: any of the largest divisions of organic life—whether it be the Animal or Vegetable Kingdom. In the Animal Kingdom, each phylum is divided into one or more subphyla, class (or superclass), subclass, family, order, genus, and species (narrowed down in that sequence).

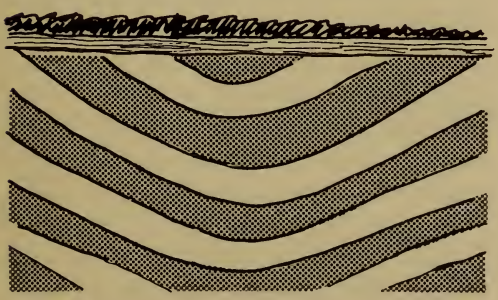
PORIFERA: the phylum of the sponges—the most primitive of all animals having more than one cell. (Reign: pre-Paleozoic to the present.) (From the Latin words meaning "to bear pores.")

PROTOZOA: the phylum of single-celled animal life. Protozoa are usually microscopic in size and include the important foraminifers. Extremely valuable as samples of pre-Paleozoic life. (Reign: pre-Paleozoic to the present.) (From the Greek words hinting at "first in time among the animals.")

PYRITES: any of a number of metallic-looking sulphide minerals. Iron disulphide ("fool's gold") is one of the commonest. The pyrites are often found as mineral replacements in fossils.

QUARTZ: crystals of silica, the chief substance of the earth's crust.

REPTILIA: a class of Tetrapoda (four-legged vertebrates) in the Chordata phylum. The reptiles include snakes, lizards, turtles, crocodiles, dinosaurs and many other picturesque bygone monsters. The body temperatures of reptiles vary with the air or water temperature. (Reign: Pennsylvanian to the present although dinosaurs and their near kin perished at the very beginning of the Cenozoic Era.) (From the Latin word meaning "to creep.")



Illus. 6 When rocks curve downward in a bowl-shaped form, they form a syncline.

SANDSTONE: rock made by sedimentation (the deposit of matter suspended in a liquid) from sand grains. It is usually fossiliferous.

SEDIMENTARY ROCKS: rocks formed from sediments or deposits in lakes and seas. Sandstone, limestone, and shale are examples of sedimentary rocks.

SHALE: an argillaceous rock that splits easily in thin sheets on the bedding plane. It contains fossils.

SILICA: as flour is the main ingredient in a pie crust, so silica (silicon and oxygen) is the chief substance of the earth's crust. Granite and sandstone are silicate rocks.

SILIFICATION: replacement of the original hard parts of an animal by silica. This type of fossilization often produces fine specimens of opalized wood (Alaska and Idaho) and animals preserved in amazingly precise detail. Sometimes, however, silification will blot out the original details.

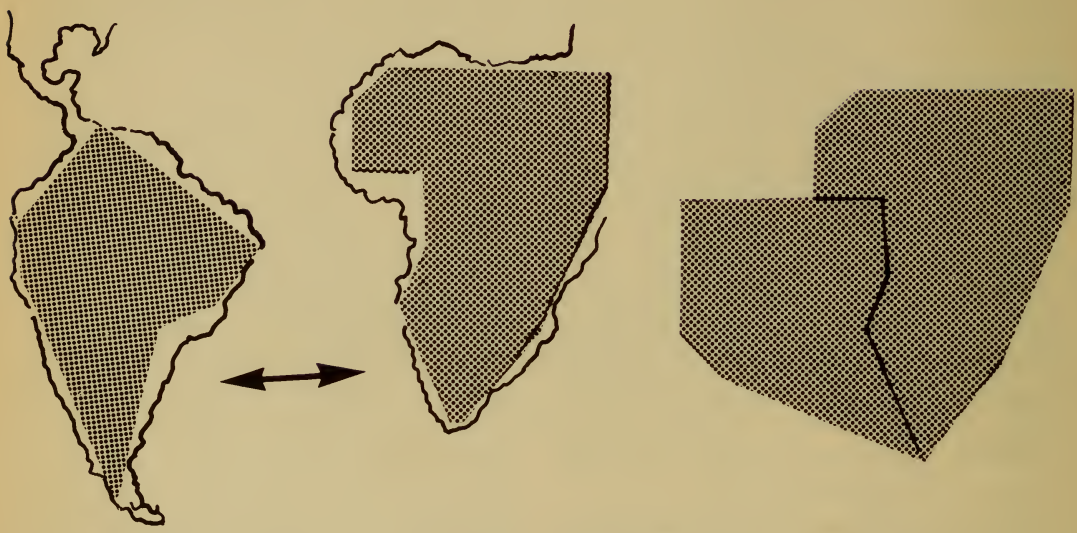
SLATE: a metamorphic rock made from shale.

SYNCLINE: a downward curve or dip in bedded rock, forming a bowl-shaped depression (see Illus. 6).

TRILOBITA: extinct class of aquatic arthropods; very important as "index-fossils." (Reign: Cambrian to Permian.) (From the Latin *tri* meaning "three" and describing the division of these sea creatures' bodies into three parts lengthwise: distinct left, central, and right lobes.

WEATHERING: the wearing action of the weather—rain, ice and wind—on a rock face. Fossils are revealed on the surface in this way.

Ancient Lands and Seas



Illus. 7 If you can visualize the two shaded land masses on the left and center put together, you will see what geologists think our two largest southern continents once looked like.

TRACE the shaded parts of the above map on "see-through" paper and then paste them onto thin cardboard. Now cut the traced areas out. You will find that they fit together like two pieces of a jigsaw puzzle. What they do is show you how Africa and South America once looked: joined together as one huge continent. What's more, geologists think that India, Australia, and what we today call "Antarctica" were once joined together with the Afro-South American land mass.

If you look now, at the outline map, you will see how this huge "six-part" continent is thought to have drifted apart. This ancient continent was called *Gondwanaland*—after "Gond," a region of very ancient rocks in India.

The land mass consisting of Africa, South America, Australia, modern Antarctica and Gondwanaland is supposed to have split up sometime after the Ordovician Period. (You will learn about various periods in the next few pages.) Perhaps it was massive disturbance of the earth's crust—volcanic eruptions continuing for millions of years—that caused it. We know for a fact that mountain ranges, for one thing, have been formed, then worn away, and sometimes re-formed by upheaval and folding of the rock strata (layers of rock). Scientists call this

mountain building OROGENY (from the Greek *oros:* "mountain" and *genesis:* "birth").

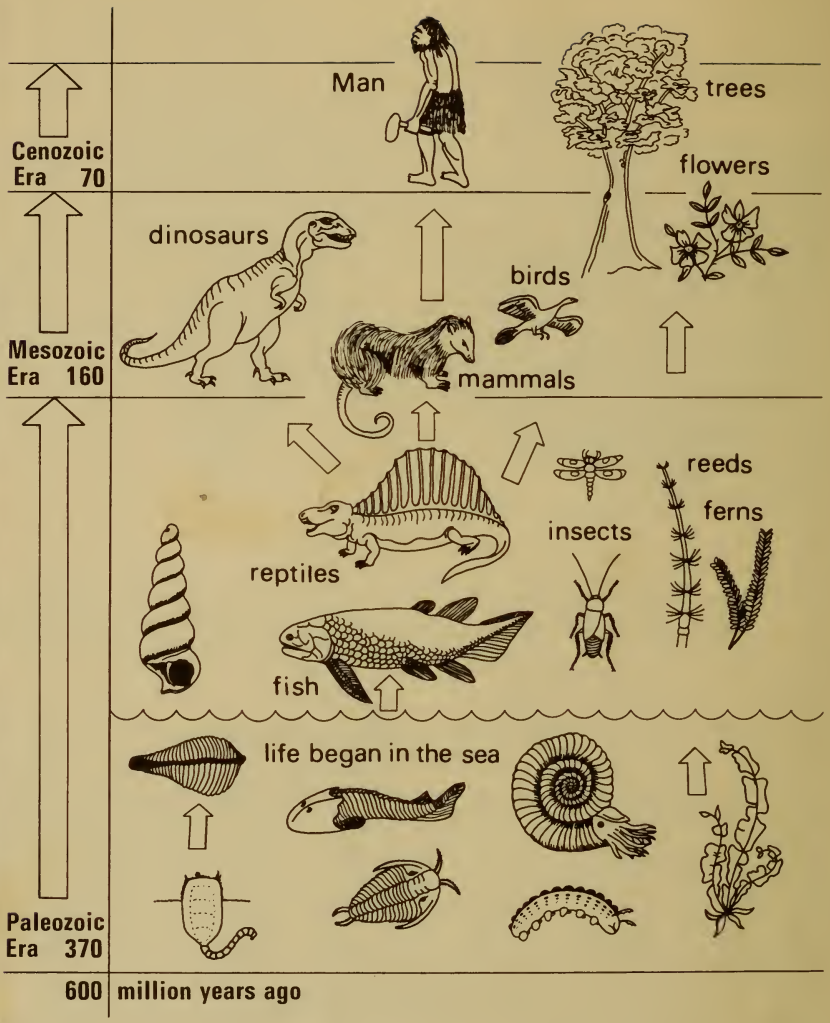
Perhaps an accumulation of orogenic upheavals caused the huge land mass to split into so many segments. At any rate, gradually and slowly, in a process that took millions upon millions of years, the various parts of the Ordovician land mass drifted while much of Gondwanaland went under water.

Is it possible for orogenic forces (mountain-building activity) to have so much power? Well, look again at the outline map. The Sea of Tethys there is actually a fairly large body of water. The Mediterranean Sea is the last vestige of Tethys.

It was violent upheavals of the rock strata (yes, orogenic activity) that eventually raised the Sea of Tethys so far above "ordinary" sea level that its bottom became the majestic mountains of the Himalayas and Alps. Our own Rocky and Appalachian Mountains are much older, as we can tell by comparing the fossils found in those mountains with fossil sea shells from what was the Sea of Tethys—(sea shells that are still to be found on Mount Everest, in fact).

It is also by collecting fossils that we can find the shore lines of the Sea of Tethys.

Illus. 8 A knowledgeable interpretation of fossils helped scientists put together this very likely picture of what our earth looked like when it was young.



Illus. 9 This time chart of three of the major earth eras is also a kind of "life-ladder." Note how the earliest fossils proved to be sea creatures—either animals or plants—and look what a long, involved climb Man had to make!

The Fossil Record

For convenience, the record of the earth and its fossils is divided into three vast eras of time:

(1) The Paleozoic Era—the "age" of life so ancient that we can barely conceive of the distance between it and us;

(2) The Mesozoic Era—the "middle-age" of life on this planet;

(3) The Cenozoic Era—the "age" of "recent" life that goes back 70 million years and yet still overtakes us here in the present.

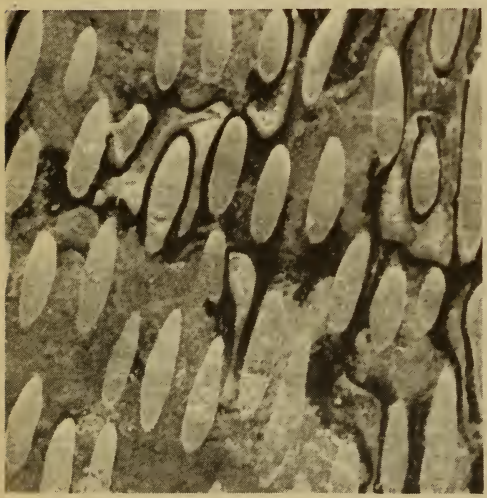
Each era is subdivided into *periods* of time, while the last era, the Cenozoic, is so accessible to us that we can break it down into *epochs*. Correspondingly, rocks, too, have their "time-divisions." A "system" equals a time period, and a rock "series" equals an epoch. An epoch can be further divided into a somewhat hazy span called an "age," while a rock series can comprise several *stages*. Note, too, that rock stages can have purely local names. For example, the Lias in Britain and the Morrison Beds in the United States are both stages of the rock system spanning the Jurassic time period. Then, too, in Europe, the Mississippian and Pennsylvanian time periods are simply lumped together as the Lower and Upper Carboniferous ("coal-producing") Period.

Before we get into a specific description of each period and corresponding rock system, take a look at the "life-ladder" (Illus. 9). Although some life forms preferred to remain in a generally recognizable state (the whelk, as we shall soon see, refused to develop a spinal column), the over-all trend is toward a more sophisticated anatomy; from seaweed to land plants that reproduced by means of spores; from these to plants utilizing in one generation the principle of male and female—and from these to flowering plants and trees; from single-celled animals to shellfish and colonial animals (the corals and bryozoa, for instance) to vertebrate fishes; and from these to amphibians, reptiles and birds—and at long last to mammals, including Man.

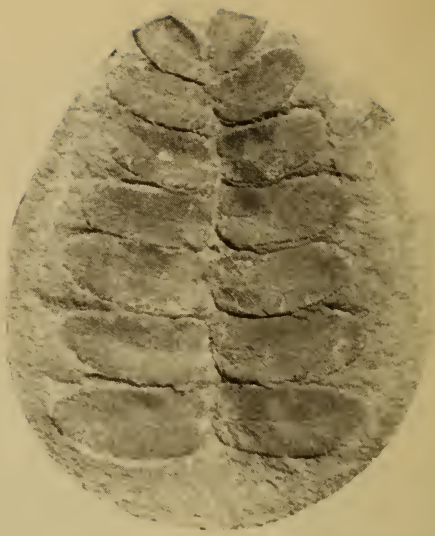
Recognizing Fossils

SINCE WE KNOW that fossils help us to discover what the earth was like before man arrived, let's take a look at a few of them, before we go on to describe the "lost" earth-ages they help us to define.

When fossils are embedded in a rock surface, they may be difficult to find. For usually they are the same color as the surrounding rock or their thickened rock encasements (matrices). Only their special shapes or outlines give them away. So you will have to develop a specialized kind of keen eyesight to collect them. Start by looking carefully at the photographs in this chapter. How many would you be able to spot as fossils? The specimen in Illus. 10 was prepared and polished before it was photographed. The white tubes revealed in the polished surface of the stone are the exoskeletons of tiny sea creatures: corals, in fact.



Illus. 10 Obviously the Lithostrotion corals lived in colonies. Here you see one, actual size.



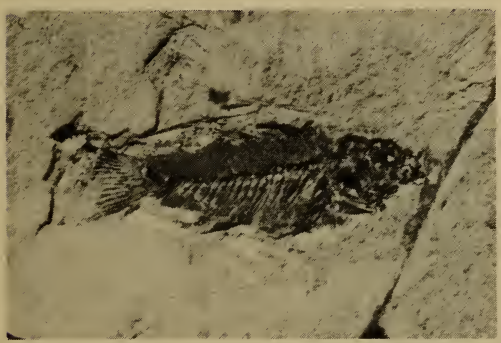
Illus. 11 Preserved as a thin strip of carbon, this Neuropteris-genus fern shows you what the plants that made our coal looked like.

And these particular corals lived back in Mississippian times.

The next fossil (Illus. 11) is also from the Mississippian Period. It is a thin film, however, and its leaf shapes set on a central stem make it clearly a plant fossil. In fact, it is part of a fern that once grew in a forest swamp. Since it dates from Mississippian times, this plant fossil, like the *Lithostrotion* corals, is about 300 million years old.

This shell (Illus. 12) was taken cleanly and without any fuss from the soft, sandy parent rock. It is the youngest fossil in this chapter, for it is only one million years old. Except for one vital difference, it is like any ordinary whelk shell. Can you tell that difference at a glance? If your answer is "no," then compare it with any other coiled shell—

Illus. 12 This Neptunea contraria lived in Pleistocene times. It is a whelk (one of the gastropods). Here, in actual size.



Illus. 13 This Jurassic fish has the scientific name Leptolepsis spattiformis. Here you see it three quarters its actual size. Compare the skeleton with that of a fish you just caught in a brook or sea.

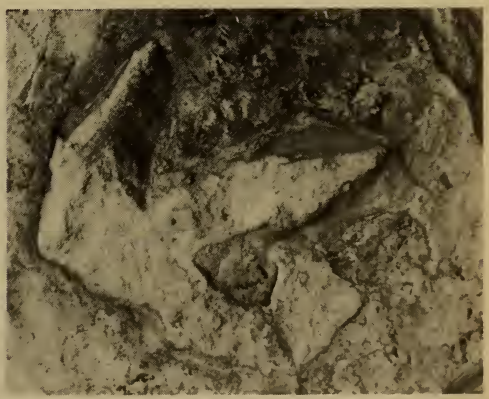
either living or fossil. If you look critically, you will see that it whirls in a contrary direction. So it has the scientific name "*Neptunea contraria.*"

Both the animal fossils you have seen so far—the corals and the gastropod (whelk) shell—are the remains of invertebrates: soft, boneless animals without backbones or spinal columns. In the next picture (Illus. 13), however, is a fish with a clearly visible skeleton including a backbone that supports the fish's head, ribs and tail. Fishlike animals, in fact, were the first vertebrate creatures.

Do you realize anything significant here? Just a paragraph ago, you were told that the youngest fossil in this chapter was the invertebrate whelk. So this fish is older. Obviously then, some animal groups did not care to develop a spinal column: it simply was not necessary for their survival (and we still have them among us today).

This particular fish is important for a good reason: it was found on dry land in Germany. Therefore, we know that the spot where the fossil hunter picked it up once lay under an ancient sea.

Would you walk past the next rock surface (Illus. 14) without a second glance? Or would you be sharp enough to notice the outline of three pointed toes? For, in fact, this is a fossil *footprint,* our legacy from a three-toed



Illus. 14 You can make Plaster of Paris casts when you come across a dinosaur footprint like this in certain parts of America (see Part III).

dinosaur as it walked in the mud 135 million years ago. The mud pressed down by the dinosaur's foot hardened and became a mold that happened to be filled in with sand of a light color. Eventually this fill-in material (the CAST) became a sandstone rock. From the size of the print, we know that the dinosaur who left us this was not one of the monster reptiles that artists love to draw. Probably, he was no bigger than an ostrich. Footprints and tracks, by the way, are important fossils—especially in Colorado, New Mexico, Texas, Wyoming, and New England's Connecticut Valley. Also invaluable are the trilobite (sea creatures) tracks in the Sahara Desert.

Remember though, fossils are not necessarily teeth or other bones, or even bone fragments. Many are simply insects that got trapped in tree resin that later petrified. (You will see one such ant in Illus. 15.) And what look like holes in rocks may actually be valuable fossils. For since worms preceded even the most primitive shellfish on this planet, their borings preserved in rocks may be among the oldest available fossils—pre-dating even Cambrian life.

Probably the geological names of the different periods under all these photographs have no meaning to you yet. But don't get "floored" by them. Come back to this chapter after you have found out what each different geological span means in terms of earth history, and the scientific labels will be almost as familiar to you as the names of the fifty states.

Illus. 15 This unfortunate ant had no idea, when it wandered into some sticky, tempting tree resin one day, that it was destined to remain trapped there for thousands of years—a prize fossil!

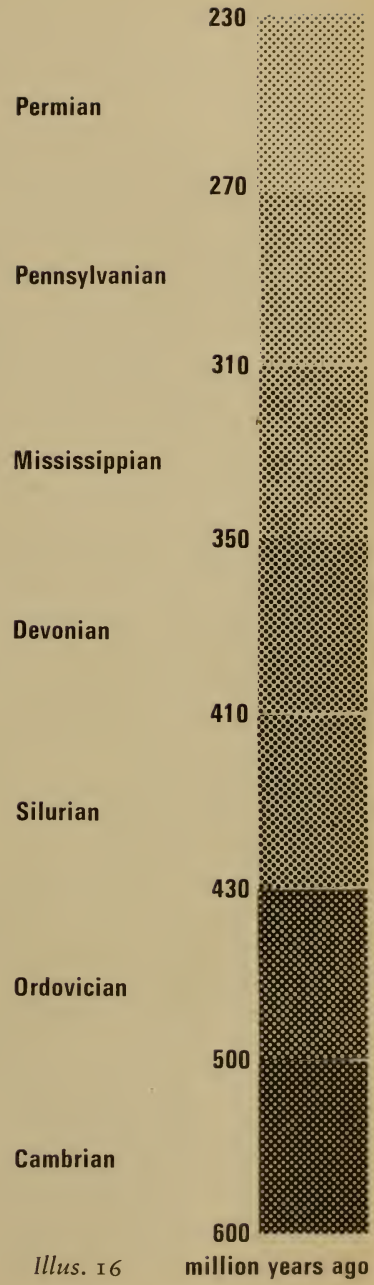
The Paleozoic Rock Systems

THE GEOLOGICAL CHART (Illus. 16) shows the systems of rocks which make up the Paleozoic Era. The name of each rock system corresponds with the *time unit*, measured in millions of years, during which that rock system was formed. Each system (and the seven almost unimaginably long periods) takes its name from that locality in the world where its rocks and strata were first studied.

The 19th-century geologists chose Wales to do a lot of their studying in, and the three oldest rock systems (and time units) of the Paleozoic Era have names connected with that country: Cambria was the Roman name for Wales; the Ordovices were an ancient tribe of northern Welshmen; the Silures occupied southern Wales.

With the exception of the reef-building algae, the lowly organisms of pre-Paleozoic times had few hard "parts" to leave behind to us. Therefore it is only with the Cambrian Period that "real" or significant fossil history begins.

What kind of a picture do these rock systems give us? Well, by assembling Cambrian fossils, we learn that the land was devoid of both plants and animals. Therefore, we can safely say that life began in the seas. And, in fact, the Cambrian seas swarmed with seaweeds, shellfish, and TRILOBITES (see Illus. 18 through 20). Furthermore, the first



Illus. 16

GRAPTOLITES (especially numerous in the ancient bygone seas of Michigan and Minnesota) were around. So were many sponges. And the first CEPHALOPODS (ancestors of the octopuses) made their appearance.

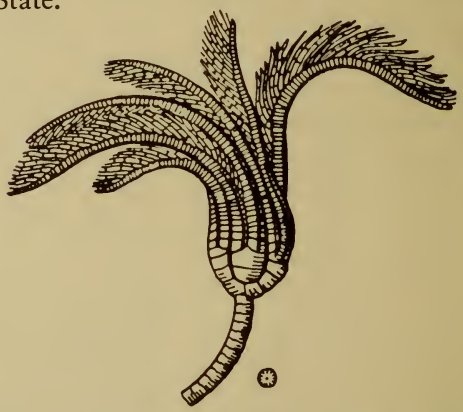
Ordovician fossils show that plant life still consisted of seaweeds and algae. Graptolites were the most numerous citizens of the oceans, and trilobites the most highly developed. Nevertheless the bryozoa, corals, ostracods (subphylum Crustacea) and starfishes made their first appearance. Most important though: the *first vertebrates* evolved. (The fragments of these OSTRACODERMS can still be picked up in Pennsylvania, South Dakota, New Jersey and the Rocky Mountain states.)

Silurian fossil records show us that somewhere in these 20 million years, plant life made "the big jump" to land. And the oxygen released by these green plants was needed to sustain the primitive animals that in later years would "try out" the land.

Meanwhile, back in the seas, marine life was thriving. The corals, for instance, were engaged in one of their greatest spurts of reef-building—as we can tell from the vast formations of chain corals and honeycomb corals in our Midwestern states.

Devonian rocks are well exposed in the British county of Devon, from which they take their name. The period is called the "Age of Fishes" because these first of the vertebrates established themselves so well during these years. Placoderms—the first fish to have jaws—joined the ostracoderms, and the first sharks appeared. In fact, fossil records show that, by the end of the Devonian Period, *the ancestors of most of our modern-day fishes had already evolved!*

The Vertebrates did not completely take over the Devonian scene, however. The Stromatopora of America were building reefs that made their time-span famous. (Some of the best of these are in Minnesota.) And the brachiopods reached a stage of development they were never to surpass, as evidenced by the spirifers of Maryland and New York State.



Illus. 17 They look like flowers, but sea lilies are actually animals.

The Mississippian Period takes its name from the upper Mississippi Valley where limestone formations abound. Sea lilies are the most characteristic animal of this period, and fossil evidence seems to indicate that whole areas of ocean beds were taken over by "gardens" of these pretty, stalked animals. Protozoa were, for the first time, abundant enough to make a contribution as rock-builders. One of their major contributions is the limestones of Indiana. And foraminifers were among the most helpful of these protozoa. Nevertheless, it is the

Illus. 18 *Olenus gibbosus is the full name of this extinct creature. Although it lived in Silurian times, this fellow is actually a very distinct relative of our popular dinner-lobster, since trilobites were also water-dwelling arthropods. This specimen is actually* 50 *mm.*

Illus. 19 *A much younger and smaller trilobite: The Calymene blumenbachi trilobites lived in Upper Cambrian times. This fellow is only* 20 *mm.*

great swamp forests, fossilized into coal, that are the first thing that comes to mind when geologists hear "Mississippian" or "Pennsylvanian" Period. (And for a long while, Pennsylvania was one of the foremost coal-producing states in the nation.) The other thing that Americans associate with the Pennsylvanian Period is bryozoa, for the moss animals were by then secure enough to concentrate on beauty of pattern instead of on mere survival. Kansas and its neighboring states excel in these especially lovely "sea mats."

Permian rocks take their name from the district of Perm in the U.S.S.R. (However, Arizona, Texas, and New Mexico have fossils of this period.) The Permian Period closes the Paleozoic Era. From its fossil records, we know that the earth's climate was becoming cooler. (All over the world, there was a sharp reduction in the coal-forming plants.)

Trilobites and Graptolites: Index-Fossils

Trilobites were marine arthropods, like crabs and lobsters. They had delicate legs that, like their bodies, were protected by a hard shell. From Illus. 18, you can see that the dorsal surface of the trilobite's shell was divided into three lobes. So the animal is called TRI-LOB-ITE. Because we can date many of these attractive fossils as Cambrian and Silurian creatures, we know that even in those very ancient seas, a well-developed animal already existed.

Not all the trilobites look like the one in Illus. 18. Look at the somewhat stouter *Calymene* trilobite, for instance (Illus. 19). The trilobites of this genus

Illus. 20 The Agnostus trilobites (Cambrian–Ordovician) were notably small (this Agnostus pisiformis is only 8 mm), and the poor fellows had no eyesight. Hold the book diagonally to see its three distinct lobes better.

frequently rolled themselves up, the way a wood louse closes into a ball for defense. So you will often find *Calymene* trilobites in this position.

The *Agnostus* (Illus. 20) was a small trilobite that, like all in his genus, *crawled* on the sea bed and was blind. Many of the larger trilobites were good swimmers, however, and had large compound eyes. (Look at the *Calymene* again.)

All the trilobites are now extinct and we can even pinpoint the Period in which they perished. Therefore they make valuable index-fossils for Paleozoic rocks.

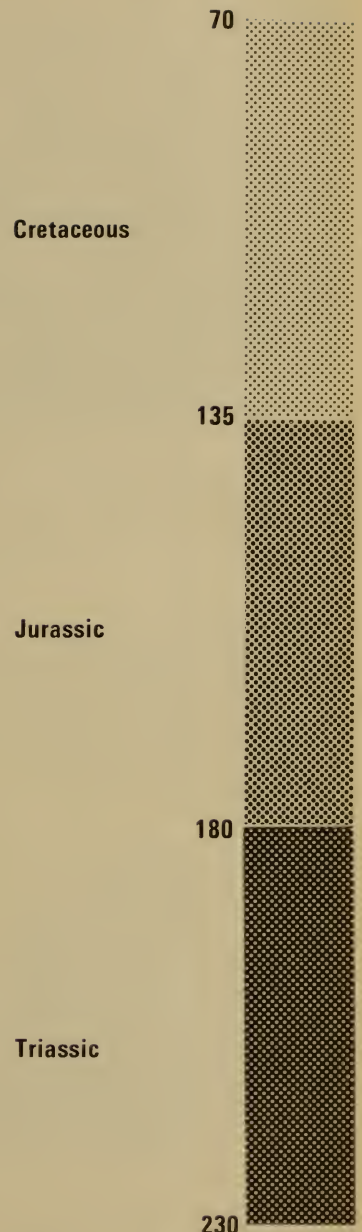
GRAPTOLITES are extinct little sea creatures that died out at the end of the Silurian Period. They were tiny polyps (little tubes of jelly) that secreted exoskeletons. Many thousands of them (colonies) lived in these shell towers, each animal having his own cell. It is their exoskeletons that remain as fossils—often found in branchlike forms. From the size of the immense deposits in Indiana, we can guess that these early creatures must have liked the state of Indiana very well—and that it must once have been an ocean area.

Because we can gauge the time-range of the graptolite, it, like the trilobite, is a valuable index-fossil for scientists trying to put together the story of the earth's past.

The Mesozoic Rock Systems

THE MIDDLE ERA of life history, the Mesozoic, may be called the Classic Age of Fossils, because relics of bygone life are so many and so varied in the Triassic, Jurassic and Cretaceous rocks of the world. From the immense number of reptile bones found in this era, we know that they were the dominant land animals, while giant turtles and amphibians ruled the seas. The Mesozoic rock systems also tell us that this was the era when DINOSAURS (see Illus. 22) stalked the earth.

Triassic rocks were first studied in northern Germany. However, they were named, not for the locality, but for the fact that scientists classified the rocks of this one period into three distinct groups. (*Trias* means "group of three.") The nature and color of Triassic rocks suggest that much of the land was desertlike. North American evidence supports this, for the Painted Desert (Arizona) and Zion Canyon (Utah) are Jurassic-to-Triassic in age. And since land reptiles are so happy in hot and dry surroundings, we can infer that this is just what the earth was like in those days.



Illus. 21

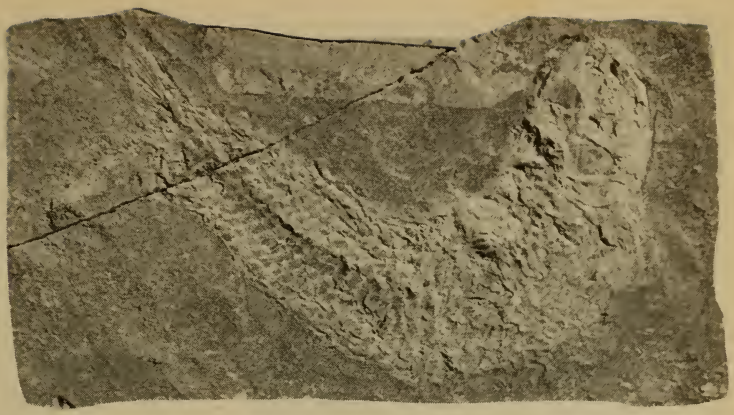
Illus. 22 By studying dinosaur bones we get an accurate idea of what these colossal beasts looked like. Here someone has made true-to-life clay models of a Brontosaurus (left) and a Stegosaurus (right). Look how different their body forms are, even though both these dinosaurs roamed the same area: Colorado and Wyoming!

From Man's point of view, however, the most interesting thing about Triassic rocks is that some of them have been found to contain fossil *fragments* of small ratlike creatures. Many geologists say these are the first of the true mammals.

The Jurassic System is named after the Jura Mountains that form part of the Franco-Swiss border. AMMONOIDS and BELEMNITES flourished in the Jurassic seas, so we know that these waters must have been warm. From the many bones found in the Jurassic water areas, we know, too, that the shelled cephalopods shared the waters with many kinds of fish and with seagoing reptiles. ["Seagoing reptiles" are animals like the ichthyosaur and plesiosaur of Colorado, Kansas and Texas: they were descended from reptiles who had for millions of years lived successfully on land masses. By going back to the sea and making it their home, they performed what is called a "secondary adaptation to marine life."] Among the fishes themselves, streamlined bony specimens like the *Pholidophorus* (Illus. 23) were typical.

Cretaceous means "chalky," from the Latin *creta,* translated as "chalk." For much of the rock laid down at this time consisted of the tiny *fragments* of sea plants and animals (although many echinoderms, especially the "heart urchins" of Texas, managed to remain fully preserved). These fragments sank in quiet waters and eventually disintegrated into enough lime deposits to form massive chalky rock. (Some of these now form chalky soils such as our Atlantic Coastal Plain.)

This period saw reptiles on the decline



Illus. 23 Pholido means "scaly," and if you look closely at this Pholidophoris-genus fish, you will see that it did indeed have a scaly covering. (Jurassic: 100 mm.)

and the end of the great race of dinosaurs.

We will take a longer look at the more spectacular participants in the "Age of Reptiles" later in this book. Right now though, let's look at some classic Mesozoic specimens that you will be more likely to find when you do your own fossil hunting. Illus. 24 shows the *Rhynconella tetrahedra* (*Rhynconella* means "shaped like a nose") and proves that brachiopods were still doing quite well in Jurassic times. All the other fossils here are mollusks—and not terribly different from our current-day shellfish. The *Pleurotomaria,* for instance (Illus. 25), a coiled-and-ornamented-shelled sea snail, can be found in many parts of the United States (see Part III). The *Gryphaea* in Illus. 26 was one of our modern-day oysters' closest "great-uncles," and its fossils are especially prevalent in Mississippi and New Jersey. Note its two unequal shells (or valves) and how the thick, larger right-hand

Illus. 24 You cannot see the stalk-hole here, but this Rhynconella tetrahedra is nevertheless a brachiopod—Jurassic, 30 mm.

Illus. 25 This Pleurotomaria anglica (55 mm) is a typical Jurassic sea snail. Note its coils.

Illus. 26 (above) Despite their unusual shape, many scientists consider the Gryphaea the first of the true oysters. Here, some Gryphaea arcuata from Jurassic times (each is 70 mm).

Illus. 27 (below) This Jurassic clam (the Lima gigantea) grew to be 180 mm. Note how careful the fossil hunters have been to protect their specimens with newspaper before leaving the field.

valve curls in to meet the thin, smaller left valve at the UMBO or hinge point which the larger shell, itself, forms.

The *Lima* is simply a large, smooth Jurassic clam. In Illus. 27, you can compare it with the mold it made in its matrix rock.

Mineral Replacement

Very often you will find bright, shiny fossils in dark shale deposits—it may even seem as if the fossil were made of gold. When this happens, the chances are that the original structure of the plant or animal has been replaced by iron pyrites, popularly called "fool's gold." The ammonite in Illus. 28 was one such fossil. Water in the rocks surrounding this Jurassic shellfish gradually dissolved the dead animal's shell and

at the same time deposited iron salt in its place. The technical name for this swapping (that probably took thousands of years) is MOLECULAR REPLACEMENT. If *you* should happen to find a pyritized fossil like the ammonite in Illus. 28, you can preserve its bright metallic appearance simply by coating it with the acetate varnish you can pick up in any hardware store.

Look now at Illus. 29. It seems to be a petrified shell. Actually, though, it is the MOLD of a Jurassic scallop. As happens so often with limy shells, this *Pseudopecten's* shell completely dissolved in the rock with no mineral replacement taking place. As a result, it left behind this hollow—but highly revealing— impression (mold).

Illus. 28 This 20-mm Harpoceras-genus ammonite was found PYRITIZED.

Illus. 29 From this likeness of a 140-mm Pseudopecten equivalvis, you can see that not only bones and shells, but molds too, give us a vivid picture of ancient life.

The Cenozoic Rock Systems

THE CENOZOIC is the shortest (and most recent) of the three eras whose life history we can chart. Covering only 70 million years, the Cenozoic is called "The Age of Mammals" because, in this brief era, the warm-blooded animals rose in great numbers to replace the reptiles as lords of the earth.

In this era, the names of all the systems correspond to time EPOCHS and all contain the Greek root *cen* meaning recent. So, first of all, we have:

the Paleocene—"the ancient recent period"

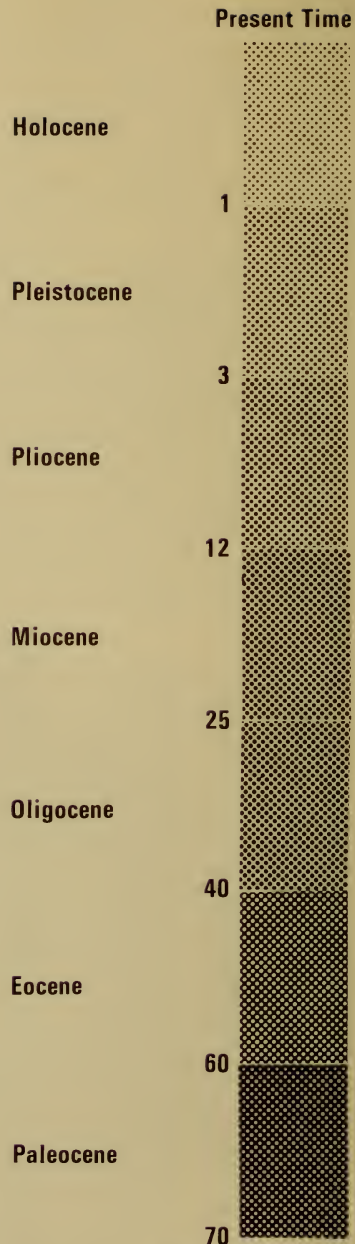
then the Eocene—"the dawn of the recent"

the Oligocene—"the little recent"

and so on.

These first three systems may be considered together because all the fossils of these times show a rapid advance on the part of both plants and animals toward the life forms of our contemporary world. Nevertheless, you will sometimes hear the first five epochs referred to as the Tertiary PERIOD—with the Pleistocene "most recent years" and the Holocene (the million years that geologists term "the present") making up the Quaternary Period.

One of the most interesting discoveries of the early Cenozoic rock systems is the fossilized bones of the horse's earliest ancestor. From their abundant deposits in Kansas, California, North Dakota and



Illus. 30

many Western states, we know that the horse originated on the North American continent—and not in Europe or Asia as many people think. The bones also show us that the horse's ancestor was a small mammal (barely 1 foot high). You can see what he looked like in Illus. 31. Although his scientific name is *Eohippus*, you may know him already as "the dawn horse."

Huge size did not guarantee survival. The dinosaurs died away completely as earth climate changed. Yet the smaller mammals increased. From the fossil record, we can trace how they adapted themselves to climate and condition of life in the forest and grasslands. Unlike the clumsier reptiles, the mammals became nimble and alert. Grass-eating animals developed long limbs and hoofed feet for running. Tree dwellers used their forelegs as arms for climbing. This was the time of the first monkeys. (The earliest known primate has been found in the Paleocene deposits of Wyoming, and not in the "Old World.")

In the Miocene ("less recent") and Pliocene ("more recent") Epochs, all the modern mammals had appeared, except Man.

Illus. 31 The charming Eohippus had 4 toes: Fossil history proves that today's horse originated in North America even though it had to be reintroduced into its home continent by the Spanish conquistadors.

It was only in deposits of the Pleistocene ("most recent") Epoch that bones of apelike men were unearthed. During the Pleistocene years there were four great invasions of ice from the North Polar Cap which covered much of the Northern Hemisphere. The last Ice Age ended 12,000 years ago, at the beginning

Illus. 32 Each of these sharks' teeth is 25 mm. And although they do not look exactly alike, all belong to sharks of the Odontaspis genus which lived, swam, and preyed back in Eocene oceans.

of the final period of fossil history. With the Holocene (wholly recent) Epoch the fossil record ends.

Sharks' teeth are found in plenty as fossils of the early Cenozoic systems. (Florida and Oregon, and South Carolina fairly swarm with them.) Sharks' teeth are an ideal find because the hard enamel covering them usually keeps them in an excellent state of preservation. Look at the various sharks' teeth in Illus. 32, for instance. Are you impressed with how sharp, polished, and fresh-looking they are? Yet all are "Middle" Eocene fossils—approximately 20 million years old!

Chama squamosa (Illus. 33) is an Eocene oyster. It is presented here so that you can compare it with the Jurassic *Gryphaea* oyster (Illus. 26). Do you realize that, for some reason, over the millions of years, the oyster found it necessary to change shape in order to survive? *Turricula rostrata* (Illus. 34.) and *Sycostoma pyrus* (Illus. 35) are sea snails that lived in warm shallow water during the Eocene years when the world climate was much hotter than it is now. Compare them with more ancient sea snail shown in Illus. 25 and you will see that their shells, too, were in a state of structural flux.

Illus. 33 A Chama squamosa, 40 mm. By Eocene times the oyster shell had evolved to be much closer to its modern shape. Can you see, though, where it still owes much to the Gryphaea's shape?

Illus. 34 A Turricula rostrata, 70 mm in actual size. Eocene snails of this species chose to form turrets with their shells.

A Living Fossil and Where It Fits

We are going to take a look now at the fossils that tell us so much about which animals ruled the world before Man arrived. First, though, it is important to get straight exactly how scientists classify life forms so that their colleagues all around the world know what they are talking and writing about.

Every organism—living or fossil—has its own name: a double one. The first

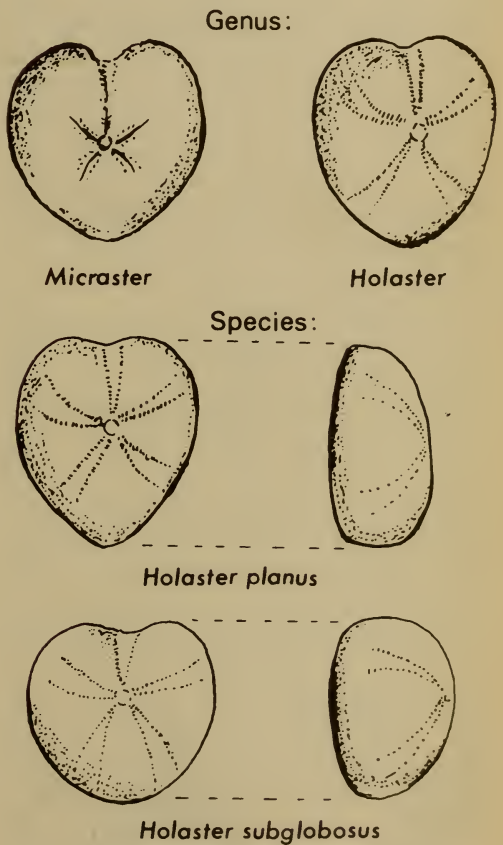
Illus. 35 You might find a shell like this Sycostoma pyrus (55 mm) on many American beaches and never realize it is an Eocene snail relic.

name refers to its genus (general name within a still broader animal category). The second, its species name, *specifies* what particular type of organism it is within its genus. It acts much like your "first" name does within your family or parents' name. However, all "names" in the Animal and Vegetable Kingdoms are expressed in Latin.

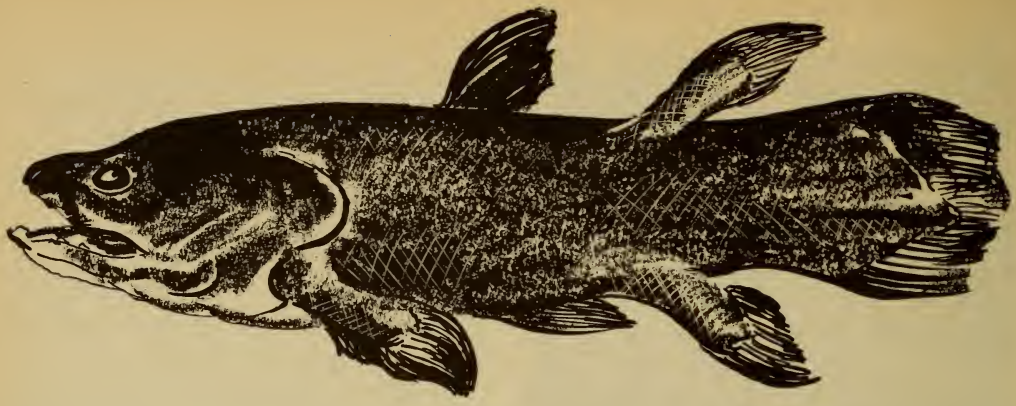
Look now at Illus. 36, where you will see how the Latin "binominal (two-name) system of classification" works. Although both of the topmost fossils can be described as heart-shaped, each belongs to a different genus. One is marked with a small star, and the other is marked with a large star. *Aster* is the Greek word for star, so the sea urchin on the left is of the *Micraster* genus, meaning "Little Star." The sea urchin on the right is of the *Holaster* genus, meaning "Whole" or "Big Star."

Next are two species of sea urchins within the *Holaster* genus. As you can see, one is flat in shape, the other is round. So their full names (their BINOMENS) are *Holaster planus* ("Big Star flattened") and *Holaster subglobosus* ("Big Star globe-shaped").

These holasters are related, in varying degrees, to all other spiny-skinned



Illus. 36 This chart makes it easier to visualize the scientific way of naming life-forms.



Illus. 37 The Latimeria chalumnae, 150 cm: Hardly appealing, but without the ancestor of this graceless-looking fish there would have been no amphibians or reptiles for mammals to evolve from!

creatures (the vast Phylum Echinodermata). The classification of natural life (of which BINOMENS are a part) produces a family tree for holasters and for every other plant and animal. This type of classification, when related to fossils, is used to explain the origin and evolution of species.

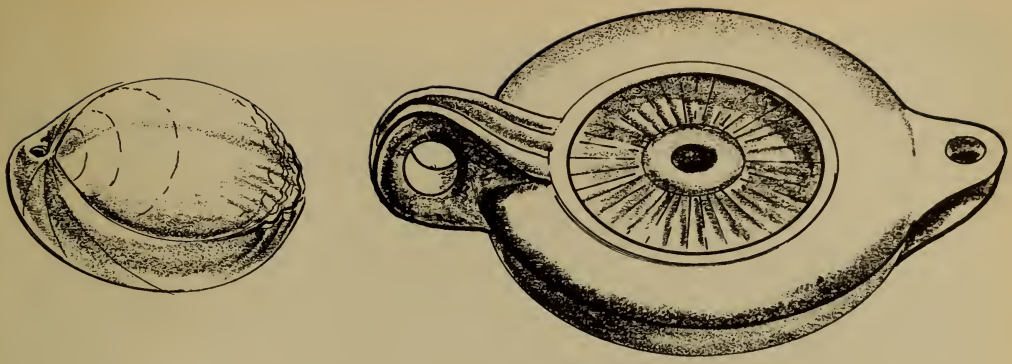
A Living Fossil-Link?

Cambrian and Ordovician fossils tell us that all life began in the seas. You know, too, that in early Paleozoic times, fishes were the highest form of life because they were the only backboned chordates. (Chordates have centralized nerve cords.) Fish were also the ancestors of all land vertebrates: the amphibians, reptiles, birds and mammals.

Geologists believed the "long-extinct" coelacanth and its fellow lobe-fishes to be the link between sea and land life. The lobe-fishes had fins that were attached to four lobes that, from fossil evidence, looked like the undeveloped limbs of a land animal. These lobe-finned fishes and their near relatives, the lungfishes, used their short, fin-ended "legs" to crawl ashore so that they could live there from time to time. Amphibians and reptiles evolved from them.

No coelacanths or lobe-fishes of any kind seemed to be swimming around anywhere, and for long centuries they were found only as fossils (a great many of them in New Jersey). Then, in 1938, a large blue fish was netted and hauled in at a port in South Africa. It was an odd-looking creature with four legs (see Illus. 37), and the fishermen who caught it had never seen such a fish before. The curator of the local museum, a Miss Latimer, recognized it as one of the lobe-fishes that was supposed to have died out in the Cretaceous Period. Here was a living fossil! Moreover, it was a descendant of the very organism that was first to bridge the gap between land and sea life!

Since then, several more coelacanths have been caught and they are now classified as the genus *Latimeria* (after the lady who identified the South African catch). The fish in Illus. 37 is nicknamed "Old Fourlegs."

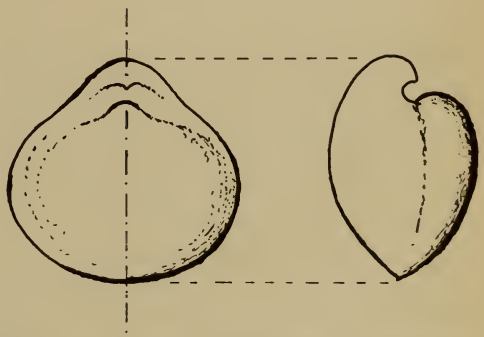


Illus. 38A (left) A Terebratula-genus shell typical of the brachiopod population in Jurassic times. Look at the stalk-hole in the shell and you will realize that brachiopods do not move freely about on their arms as their Greek name mistakenly implies. Illus. 38B (right) Roman pottery lamps might as well have been modeled after brachiopod shells!

Brachiopods

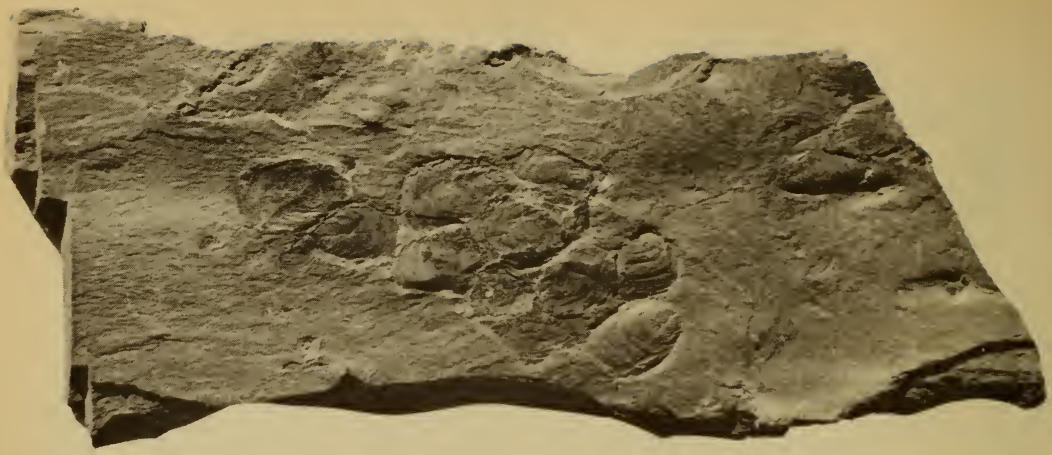
BRACHIOPODS ARE SHELLFISH of a primitive type, the living creature being anchored to the sea by a PEDICLE (a kind of stalk) that emerges from the beak of the animal's shell. (Look at the "pedicle hole" in Illus. 38A.) Although they are common as fossils of the Paleozoic and Mesozoic Eras, the brachiopods are today a declining race.

If you plan to spend any time at all collecting fossils, it is important for you to learn the difference between brachiopods and the bivalved shellfish of the mollusk phylum—scallops, for instance. Illus. 39 and 40 will help you. Look first at the full view of a brachiopod in Illus. 39 and note how regular or symmetrical it is on an imaginary center line drawn down from the beak. Now compare the side view of a brachiopod with the *Protocardia* mollusk in Illus. 40. This is a simple way to distinguish between the two phyla.



Illus. 39 (above) One way to tell a brachiopod fossil out in the field is to determine if it is as symmetrical as the shell here.

Illus. 40 (below) Note how the valves of this mollusk form a pair.



Illus. 41 A collection of Lingulella davisi brachiopods (190 mm) preserved in rock that was once sand on the bottom of an ocean. Obviously, these shellfish got some kind of security from clustering together. The Lingulella brachiopods flourished in Lower Cambrian times, but there are still some species of Lingulella surviving in our own seas!

How did the brachiopods get along? Over 500 million years ago, the Cambrian fossil *Lingulella* (Illus. 41) was a living shellfish that burrowed in the Cambrian sands. Our living *Lingula* or "goosebill" is similar in shape and life habit to this ancient creature. Now you know one reason why we say the brachiopods are "primitive": there has been so little noticeable evolution since Cambrian times!

You will often hear some types of brachiopods being called "lamp shells." Compare Illus. 38A with the old Roman lamp in Illus. 39B and you will see why. The *Terebratula* and many other species are shaped like the oil lamps of ancient times, and their pedicle holes resemble wick holes.

Mollusks

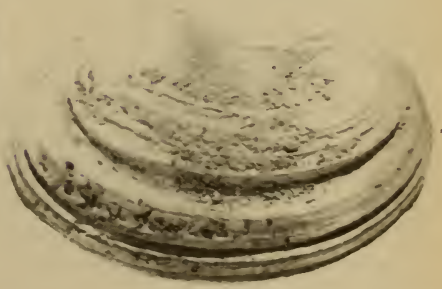
THERE ARE THREE important classes in the soft-bodied mollusk phylum:

(1) Lamellibranchs (often called pelecypods)—oysters, mussels, clams, scallops.

(2) Gastropods—snails, whelks, limpets.

(3) Cephalopods—squids, nautiluses, and the extinct ammonoids.

Protocardia truncata (Illus. 40), *Oxytoma cygnipes* (Illus. 42) and *Spisula arcuata* (Illus. 43) are fossil examples of the Lamellibranchs (this Greek name refers to the mollusks' platelike gill structures). Because all the Lamellibranchs have two shells (or valves) that form a pair, they are called "bivalves." The soft-bodied creature inside the Lamellibranch shell has a fleshy, hatchet-shaped foot. This accounts for its name "pelecypod."



Illus. 42 (left) Compare the shell ribbing of this Jurassic lamellibranch (or pelecypod), the 75-mm Oxytoma cygnipes, with the spherical coils of the much younger pelecypod in Illus. 43.

Illus. 43 (right) A Spisula arcuata (65 mm) that inhabited the Pliocene world.

Gastropods are univalves; they have only one shell and that is carried *above* the body. (The gastropod walks on his stomach, remember.) The animal can withdraw into its shell and close its entrance with a hard plate, called an operculum. Although not common in Paleozoic rocks, fossil gastropods are abundant in Mesozoic and Cenozoic formations. The *Volutaspina* (Illus. 44) is a fossilized gastropod whose coil is ornamented with spines. You will see many shells of this type on the South Jersey shores, but the *Volutaspina* is only one example of the many different fossils in the gastropod class. A good sampling, too, is presented throughout this book.

Illus. 44 Living shellfish related to this GASTROPOD prefer warm seas. So if you find a fossil like this Volutaspina, you can safely judge that the area was once semi-tropical. Here, a Pliocene specimen, 70 mm.

Cephalopods

THE CEPHALOPODS are such frequently encountered fossils that you will need a whole chapter to learn about them. They are the highest class in the mollusk phylum because they have a head distinct from the body and because their nervous systems and digestive organs are more highly developed than those of the animals in the other mollusk classes. Actually, cephalopods have a "head-foot," with tentacles serving as the foot part and being set around the head part (where the animal's nervous system is based) in the shell opening. All this is only one organ, as you can see from Illus. 45 and 46.

The cephalopods are categorized as follows:

Phylum: Mollusca
Class: Cephalopoda
Orders:
(1) Nautiloidea (nautiluses)
(2) Ammonoidea [ammonoids, including the goniatites so important as

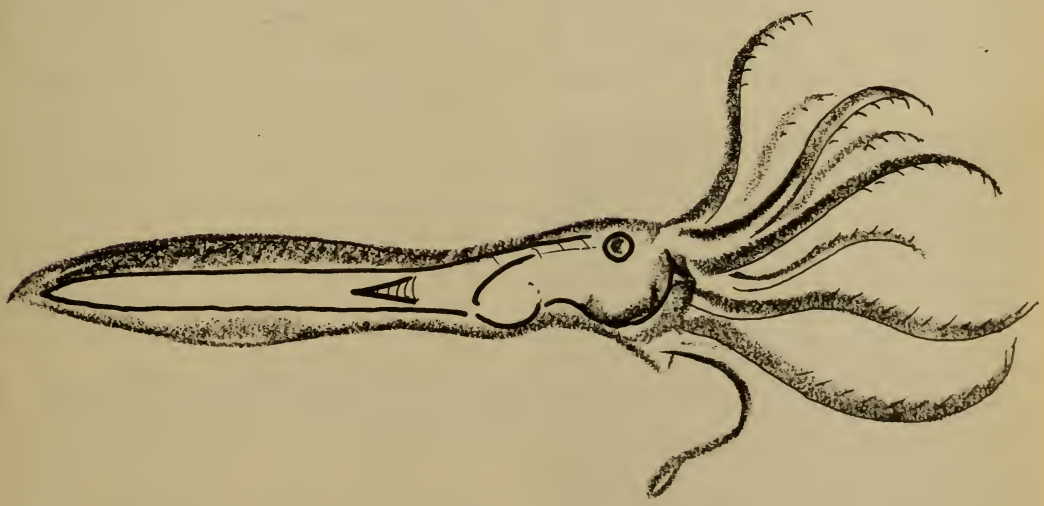
Illus. 45 A cephalopod head has been clay-modeled and inserted in this empty ammonite shell to show you what the creatures looked like when alive.

index-fossils, and ammonites (any ammonoid whose precise species we cannot identify—you will find many of them in this book)]

(3) Dibranchia: squids, octopuses, and belemnites.

The ammonoids and belemnites are now extinct. The nautiloids (nautiluses) appeared early in the Paleozoic Era as the first cephalopods and are still with us. Their fossil shells are formed as straight, tapered cones and may be of "giant" size: over 3 yards long. Minnesota has some of the largest and most notable nautiloid fossils in the country.

A spiral curled shell is distinctive of



Illus. 46 Belemnites are also cephalopods. Here, one positioned as in life. Study its head.

Illus. 47 Alexander the Great as Ammon: Compare the horns and curling hair with the design of any ammonite shell.

Illus. 49 Cross-section of a Hildoceras bifrons, an ammonoid quite distinct from the Goniatites—and one typical of the Jurassic Period (125 mm).

the ammonoids, sea creatures that take their name from the ancient Egyptian god Ammon. On Greek and Roman coins his head appears with ram's horns curling back from the forehead (see Illus. 47).

GONIATITES were the first ammonoids, and you can recognize their fossils easily by the bold chevron (zigzag lines you have seen so often on policemen's or servicemen's uniforms) on the shells—Illus. 48 for instance. These chevrons are actually SUTURE ("stitched effect") lines that mark off the various chambers of the shell.

In Illus. 49 another ammonoid shell has been cut open to reveal all the chambers, which were added one by one as the living mollusk grew older. The last (and largest) chamber was occupied by the soft body of the animal. The other, smaller chambers were empty. We believe that the animal filled them with air or water by means of his siphuncle (a membranous tube that is an extension of the soft mantle) and thus used these chambers as buoyancy tanks. Long ago, the ammonoids had already figured out the principle of our modern-day submarines!

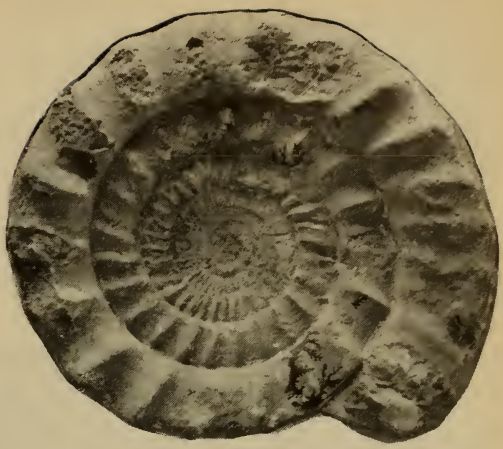
Illus. 48 Compare the bold zigzag pattern on this goniatite shell with the very different suture marks of other ammonoids. Here a Goniatites ammonite that lived back in Mississippian times (60 mm).

The goniatites perished by the end of the Permian Period, but the Jurassic oceans must have swarmed with other ammonoids (and ammonites), for they are found in great numbers as fossils of this eon. They are classified into genera and species according to the number of turns in the spiral of their shells (the number of ribs on their shells), whether they have or lack a keel (an outer rim to their shell coils) and the nature of the cross-sections of their whorls (spiral turns).

In Illus. 50, you see a "giant" ammonoid—the *Arisphinctes maximus* that often grew to 3 feet or more! Part of the shell has been removed here to reveal the suture pattern. Note how fine it is: like the branchings of a tree. Moreover, since suture lines show the position of the walls that divide a shell into separate chambers, we know that this Jurassic ammonoid was intricately chambered. Compare this fossil with the Triassic *Ceratite* on page 88 where the sutures are just simple wavy lines. (Nevada, incidentally, provides a vivid contrast in ammonoid patterns as they vary through the Triassic and Jurassic eons.)

Belemnites were like our still surviving cuttlefish (although some people place them in a special sub-branch of the Dibranchia category). They did not have a hollow shell, but the fleshy mantle of these creatures enclosed a hard rod that was like a cigar in size and shape. Attached to this hard rod was a small hollow shell (the belemnite's PHRAGMACONE) as Illus. 51 shows. It is the rod or "guard" that you will find as the fossil.

You can find out more about the belemnites in Part III as Georgia and New York are quite rich in their fossils.



Illus. 50 Compare the suture pattern of this Arisphinctes maximus (another Jurassic ammonoid) with the chambers revealed in Illus. 49. This Arisphinctes, though, is 480 mm!

Illus. 51 From this actual belemnite fossil, learn the most often preserved parts: (1) guard; (2) phragmacone; (3) pro astracum. This is a 210-mm Acrocoelithes from a Jurassic sea.

Illus. 52A. Sea lilies belong to the Pelmatozoa (or non-free-moving) subphylum of the Echinoderms. Here, a Pentacrinus-genus fossil from Jurassic times. It measures 150 mm.

THE STARFISH and the sea lily are both sea animals related within the phylum Echinodermata. The first is free moving; the second attached or stalked, characteristics that decide which of the two subphyla of echinoderms, each spiny-skinned creature will fall into.

The stalked types such as sea lilies and blastoids abound in many Paleozoic rocks of the U.S.—Kentucky, Michigan, and Missouri to name just a few highly favored states.

Echinoids or sea urchins are common fossils in limestone rocks of the Cretaceous Period. You saw some of them in Illus. 36. And if you live in Georgia you will have a chance to see a lot more.

The shape of some echinoderms is based on a five-sided figure: the pentagon. Perhaps the starfish is the most dramatic of these spiny-skinned sea creatures, both "attached" and free swimming. Their bodies can be divided up into five recognizable segments. Illus. 52B shows you one of these: a Jurassic starfish. And note how, in Illus. 52A, the ossicles or small bones of the *Pentacrinus* sea lily also resemble separate, PENTAGONAL beads of a broken necklace.

Illus. 52B. This starfish is also a Jurassic echinoderm. It can swim freely, however, and so belongs to the Eleutherozoa subphylum. This fossil's name is Ophioderma tenuibrachiata.

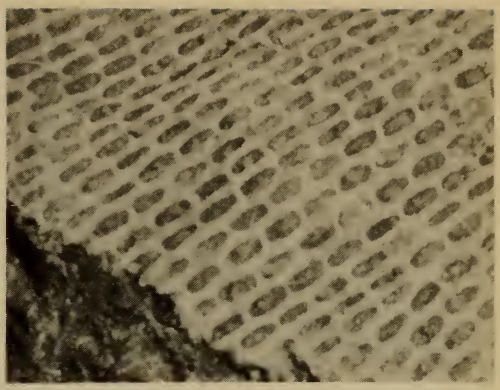
Corals and the Like

CORALS AND SEA ANEMONES look like plants growing in an underwater garden, in the clear shallow seas where they are found. They are not plants, however, but animals and are related to jellyfish and the extinct graptolites and stromatoporoids in the phylum Coelenterata. For like all the Coelenterata, they are really just a mouth and a gut formed of jelly.

Corals have a hard limy exoskeleton and usually live in colonies. There are so many "members" to a colony that massive reefs are formed from their remains. *Halysites,* the chain coral (one small colony is shown in Illus. 53); *Favosites,* the honeycomb corals; and the cup corals are the genera that formed most of the coral reefs in the U.S.

Illus. 53 Do you see why the type of corals that build colonies like the one on this rock are called "chain corals"? This particular colony dates from Silurian times. (Halysites catenulates: 90 mm.)

Some of the larger corals are found singly as cone-shaped fossils. But whether "solitary" or colonial, fossil coral abounds in limestone rocks that have been formed as sediments in shallow seas. Therefore we can use these ancient formations to trace the shores and coastlines of America's bygone seas. (The Stromatopora reefs, prevalent in many parts of America, afford us the same "detective" opportunity.)

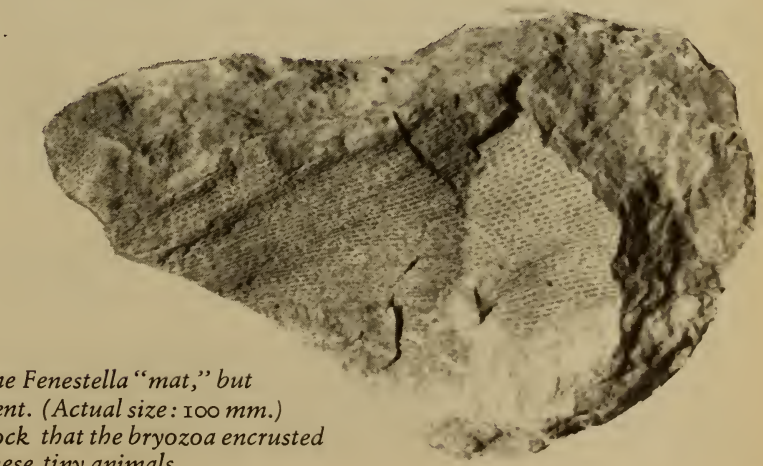


Illus. 54 Bryozoa, too, form lasting exoskeletons. You should be able to see the window shapes very clearly in this enlargement of a Pennsylvanian bryozoa settlement.

Bryozoa

These sea animals earn their phylum name, which means "moss animals," because they creep or spread out like moss-growth patterns. They also fully deserve another frequently used name (Polyzoa meaning "many animals") because the exoskeleton mass is a colony of separate animals, each staying strictly within the limits of his own cell. *Fenestella* means "little window" in Latin, so a certain group of bryozoa whose empty exoskeletons create a windowlike effect, gets the genus name *Fenestella.* Illus. 54 and 55 show you a fossilized *Fenestella* colony.

You will often find bryozoa encrusting the surface of marine shells, sea fossils, and rocks that once lay under ancient waters. So if you live in an area where bryozoa abound, you should realize that your community was once submerged in a bygone sea or lake.



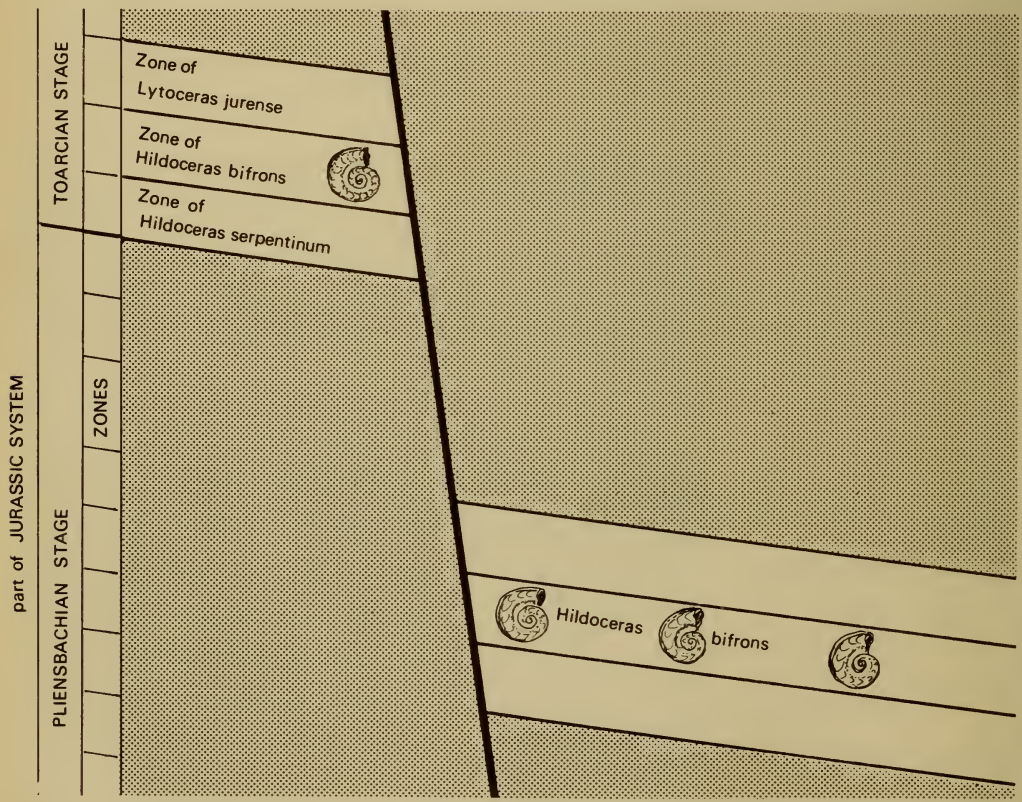
Illus. 55 This is the same Fenestella "mat," but without any enlargement. (Actual size: 100 mm.) Here you can see the rock that the bryozoa encrusted —a favorite habit of these tiny animals.

Stratigraphy

STRATIGRAPHY is the study of the layers of rock that form the earth's crust (its STRATA). Illus. 56 is a diagram of a rock face of the Jurassic rock system with the strata marked off in stages and zones. This precise identification is made possible by having found a special fossil within each zone, one belonging to it alone: called an INDEX-fossil or ZONAL-fossil.

On the left of Illus. 56, note the three zones. These three zones stop abruptly at a perpendicular line and then continue lower down, right of that line. The line is a crack or FAULT where the strata have been broken by some disturbance in the earth's crust. The three zones once formed a level and continuous band of rock, for the zonal-fossils are found in their correct order on each side of the fault. So, by means of ZONAL-FOSSILS, you can learn to recognize and match up rocks in different parts of your neighborhood.

Note that all the zonal-fossils in this diagram are ammonoids. These extinct shellfish swarmed the seas in Jurassic times. Therefore, they make ideal zonal-fossils to help you identify the strata of this period.



Illus. 56 Index- (or zonal-) fossils make it possible for us to precisely date various strata.

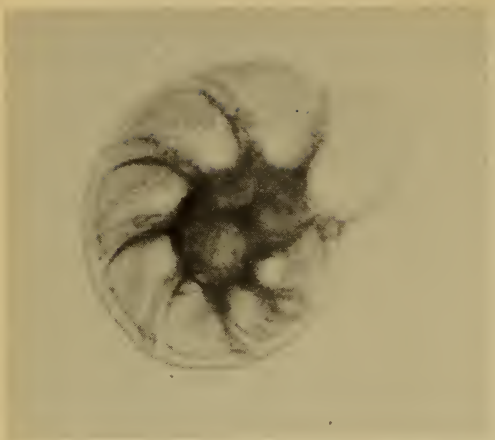
Illus. 57 You cannot see the paleontologists at work here, but they will eventually draw up a map of rock formations that are far below the earth's surface. And oil derricks will follow! Right now, they are compiling their information on the basis of INDEX-*fossils.*

Oil

PALEONTOLOGISTS are engaged in the search for oil. They are making a chart of deep rock formations from samples brought up from underground by a drilling rig.

The drill-core samples have been examined under a microscope for fossilized *Foraminifera,* a type of protozoa whose shells are no bigger than grains of dust. Nevertheless, these tiny sea protozoa, with their many shell forms (Illus. 58 shows you one species of shell), are important zonal-fossils. For they serve as a guide to the oil-bearing rocks. Oil companies employ many men just to sort out the various layers of rocks according to the fossils found in them.

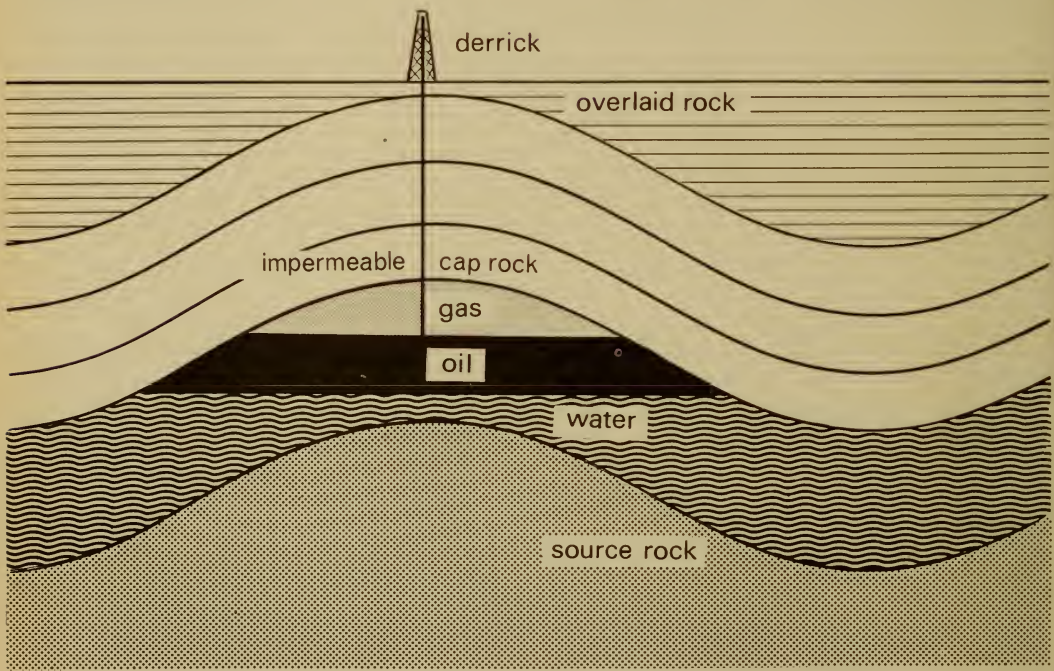
CRUDE oil is called petroleum, a word made up from the Latin *petra* (rock) and *oleum* (oil). Oil is actually the remains of abundant natural life of ancient sea beds, transformed in the deep rocks, into a thick, valuable fluid. So an oil field is a kind of reservoir: one where ancient,



Illus. 58 The Foraminifers are among the most rewarding of fossils also because of their beautiful shapes. Here (enlarged), the shell of a Foraminifer protozoa.

liquidized sea life is trapped in an ANTICLINE, a geological formation of rocks like an inverted saucer. Oil seeps UP through sandstone and water-bearing rocks and then accumulates under a cap of rock such as clay and shale (through which it cannot pass). There it lies trapped until men familiar with *Foraminifera* find it as an underground lake.

You yourself can do a simple experiment to "see" how oil seeps up through porous rock: Pour about one half inch of old engine oil into a clean glass jar. Then add the same volumes of sand and water. Give the mixture time to settle, and you will see the oil rise clear of the sand and water. Illus. 59 shows you this on a commercial scale.



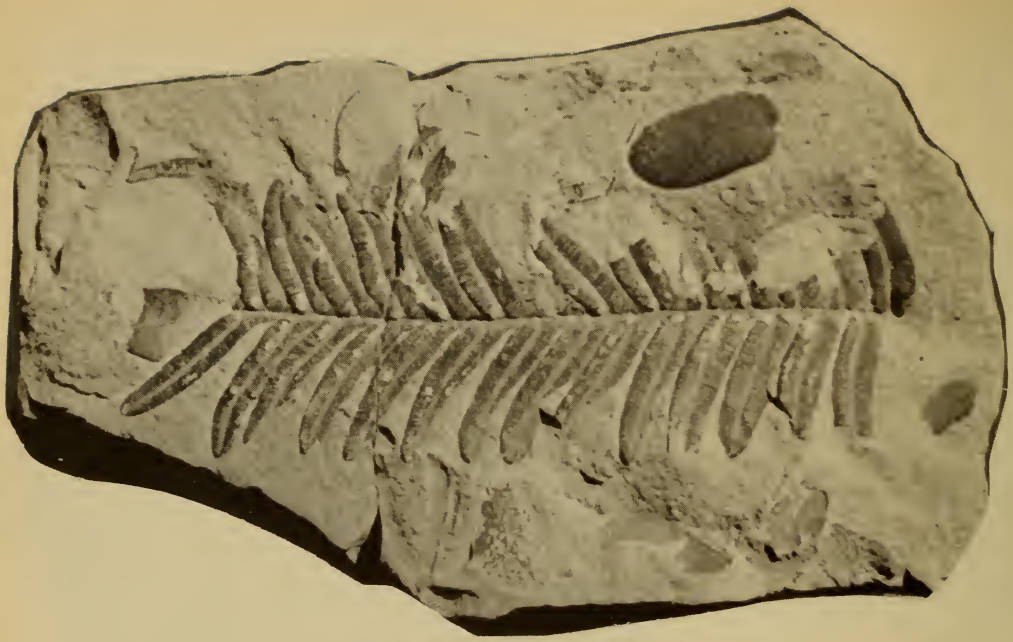
Illus. 59 Diagram of what underlies an ordinary oil derrick.

Illus. 60 This is a piece of fossilized bark from Pennsylvanian time. Many trees of that lush, bygone Period were Lepidodendrons that grew 100 feet tall.

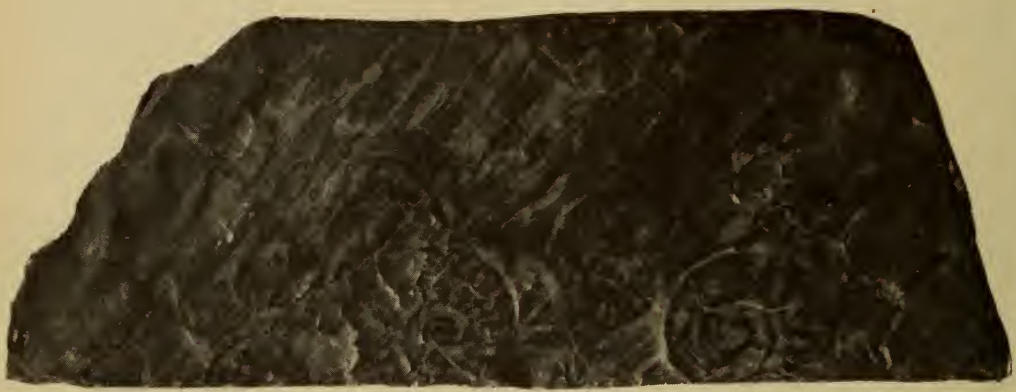
Plant Fossils

COAL is the most famous of the plant fossils. Back in the Mississippian and Pennsylvanian Periods (some 300 million years ago), the lowlands of the earth were vast swamps thickly covered with green vegetation. In the hot damp air, giant trees and ferns grew in thick forests, then died and sank in the mud. Insects, too, were giant, as they flew in the forests of tall, primitive trees and lush undergrowth. Meanwhile, amphibian reptiles were living and evolving in the stagnant pools and slow-moving rivers of the swamps.

The huge forest trees were early conifers (now extinct) and giant club mosses. The *Lepidodendron* (Illus. 60) was very common in these forests. The name means "scaled tree" and refers to the leaf scars that make the stems of these trees look scaly—like reptile skins perhaps. You can see the scar pattern very clearly in this illustration.



Illus. 61 The ferns of Pennsylvanian time were also huge. Here, part of an Alethopteris-genus fern (98% of actual size) preserved for us as a strip of carbon.



Illus. 62 This elegant jet was once a piece of nondescript driftwood. Any jewelry-maker would be happy to have it, but it is especially important to us because of the ammonite impressions it has managed to retain.

The *Alethopteris* (Illus. 61) is not a tree fossil, but a relic of one of the many large forest ferns of Pennsylvanian and Mississippian times. Here the leaf form is beautifully reproduced in a thin carbon film on the ancient stone.

You also have a good chance of finding the fossilized reedlike stems of giant EQUISETUMS dating from these periods. These huge plants are the near relatives of our common horsetail weed of today, so again we can trace a genus backward.

Nevertheless, most plant life of the Pennsylvanian and Mississippian years has been pressed into a black, shiny, solid mass: coal. Mined extensively in the SEAMS of the rocks of these periods, coal retains no trace of the shapes of the leaves and plant stems that went into its making. Still, you will be able to find such plant fossils in the sediments laid above and below the seams of coal.

Amber and Jet

Amber and jet are both glassy substances of fossil origin, and both are derived from ancient trees. Jet, black and lustrous, is found as pieces of ancient driftwood (Illus. 62). Beads, brooches, earrings, and other ornaments made of this fossil were very popular in the 19th century.

With its rich shades of red and yellow and its semi-see-through quality, amber was also used in the old days. Cut and polished into beads for necklaces, it was much prized by the Greeks and Romans. Centuries later, it was shaped and bored to make pipe stems and cigar holders (Illus. 63).

Amber was originally resin, exuded from conifer trees in the warm summers of early Cenozoic times. It was this living, sticky gum that trapped and engulfed ancient flies and other insects in its soft, oozing mass (Illus. 15). When the resin hardened and fossilized, it became "amber." And polished amber that reveals entrapped insects is still highly prized jewelry. The Baltic coastlines were famous in classical times for this ornamental fossil, but Russia and Alaska also are chief sources today.

Illus. 63 It is hard to believe that this stylish cigar holder was once gummy tree resin, but this is an amber ornament. Note, too, the insect trapped near the bottom.

Illus. 64 The sheer size of dinosaurs presents a picture of our planet that strikes awe into Man!—especially when we realize that plants, water holes, and other earth features must have been proportionate to them. Here, visitors go through the Dinosaur Room at the Carnegie Museum.

Dinosaurs

EARLY IN THE 19TH CENTURY, fossil fragments of teeth and other bones, all resembling a crocodile, were found in England. They were classified as the remains of a DINOSAUR, which means "terrible lizard" from the Greek *deinos* (terrible) and *sauros* (lizard). Except for the name, however, little more was known of these creatures until many years later, when huge fossilized bones were found in the Badlands of Colorado and Wyoming. These bones proved that the dinosaurs were, indeed, terrifying in size. Two American paleontologists, Othniel Charles Marsh and Edward Drinker Cope, worked separately and as rivals over the years, to find more of the bones and restore them as complete skeletons.

In big-city museums all over America, the Carnegie Institute in Pittsburgh and the American Museum of Natural History, New York City, for instance, these dinosaur skeletons capture the popular imagination. Other museums, which lack actual skeletons, often have full-sized statues of these creatures—Dinosaur State Park in Rocky Hill, Connecticut, for instance, and the Chicago Natural History Museum.

In comic books and films the dinosaur eternally chases the Stone Age man. This is false, however, for the great race of dinosaurs died out at the end of the Mesozoic Era—long before Man first arrived on the scene.

Many of the dinosaurs were harmless, vegetation-eating monsters: (HERBIVORES). The *Brontosaurus,* for instance, lived in swamps and fed on reeds and grass. *Triceratops* was a grass-eater of the plains, equipped with an armor of bony plates and horns, which he used only for defense.

On the other hand, there were fierce dinosaurs who preyed on more helpless animals—including their own kin, the herb-eating dinosaurs! These fall into the category of flesh-eating animals: the CARNIVORES. One such vicious giant was the *Tyrannosaurus.* With sharp teeth set in huge, powerful jaws, he is well named "the tyrant dinosaur."

Illus. 65 The Dilophosaurus was a 20-foot-long dinosaur that roamed Arizona. From reconstruction of its bones, we know that the monster looked much like this. Compare this graceful-looking dinosaur with the Brontosaurus and Stegosaurus re-creation in Illus. 22.

Following are some of the commonest dinosaurs that populated America during Jurassic and Cretaceous times:

HERBIVORES (length from head to tail)

Brontosaurus ("thunder lizard"): usually 70 feet; fond of Colorado and Wyoming.

Diplodocus ("double-beam bone"): usually 80 feet; also fond of Colorado and Wyoming.

Stegosaurus ("covered lizard"): usually 20 feet long but with a $2\frac{1}{2}$ ounce brain; fond of Colorado, Utah and Wyoming.

Triceratops ("three-horned"): usually 25 feet long; fond of Montana and Wyoming.

CARNIVORES:

Tyrannosaurus ("tyrant lizard"): usually 45 feet long: found in Montana and South Dakota.

Ceratosaurus ("horned lizard"): usually 19 feet long; found throughout the American Northwest.

[Connecticut's famous dinosaur tracks were made by *Triassic* dinosaurs. They were probably similar or very closely related to Arizona's 20-foot-long *Dilophosaurus* (a carnivore). The smaller tracks were probably made by the *Coelophysis,* since some of his bones are still found in Connecticut and the bones seem to match the footprints.]

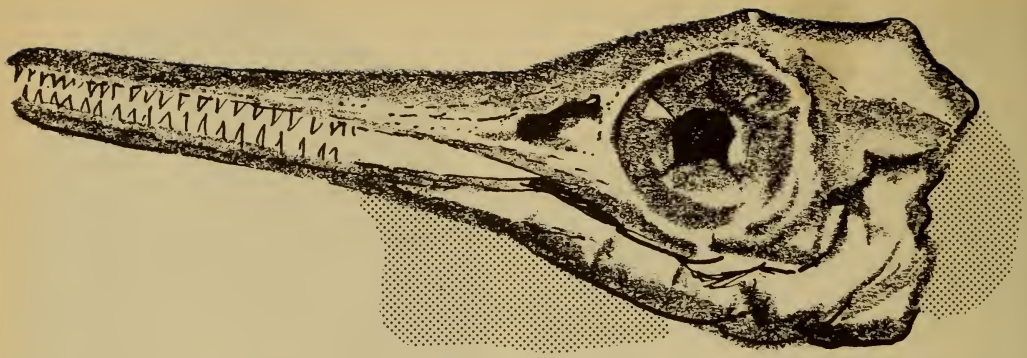
The End of a Race

The dinosaurs not only lived, but *ruled* for 100 million years and then died out quite quickly at the end of the Cretaceous Period. Why did they become extinct? Some scientists believe they became so big and clumsy that, at last, they were no longer able to look after themselves. But this does not

explain why they lasted so long as the leading reptiles of the Mesozoic Era.

It is more probable that earth conditions no longer favored the dinosaur. At the end of the Cretaceous Period, there were changes in land surfaces through orogenic movement (mountain building such as the earth upheaval that formed the Rocky Mountain System). And the climate became colder. The warm swamp, the home of the dinosaurs, died out and became cold uplands. Deprived of their swampland foods, the dinosaurs probably dwindled in number and then died of starvation. Some species, of course, perished simply from the cold. Whatever the cause, it was now the turn of the mammals.

Illus. 66 Even the eggs of dinosaurs (right) are huge. The early mammals loved to eat them, and some scientists think this contributed to the end of the reptile-lords.



Illus. 67 Look closely at this artist's reconstruction of an ichthyosaur skull, and you will realize how much it looks like the skull of a giant fish having jagged teeth in its snout.

A Girl Who Found a Fossil Reptile

In 1811, a twelve-year-old British girl made one of the most important finds in all fossil history. Her name was Mary Anning, and she lived in a coastal region of Britain where Jurassic rocks abound. As a young child, Mary Anning was already helping to support her family: she collected ammonites and other fossil shells to sell to summer visitors to her seaside town. But she was also gaining practical experience with fossils: something more valuable than book learning and museum study. So when she came upon a complete skeleton one day, she was able to dig it up carefully and without harming it. The fossil looked like a giant fish (see Illus. 67), but proved to be a reptile that had gone back to the sea to live. In fact, it was the *Ichthyosaurus* or "fish-lizard." Mary Anning's find was the first whole specimen of this extinct reptile. Formerly it had been known—but only by odd fragments of its bones.

As she grew older, Mary Anning became an expert on Jurassic specimens and made many other important finds—the sea reptile *Plesiosaurus* and the flying reptile *Dimorphodon.* Her success in this work lay not in strokes of luck, but in keen observation and knowledge of ancient life. For fossils can be seen very readily in rocks, once you have trained your eyes to watch for them.

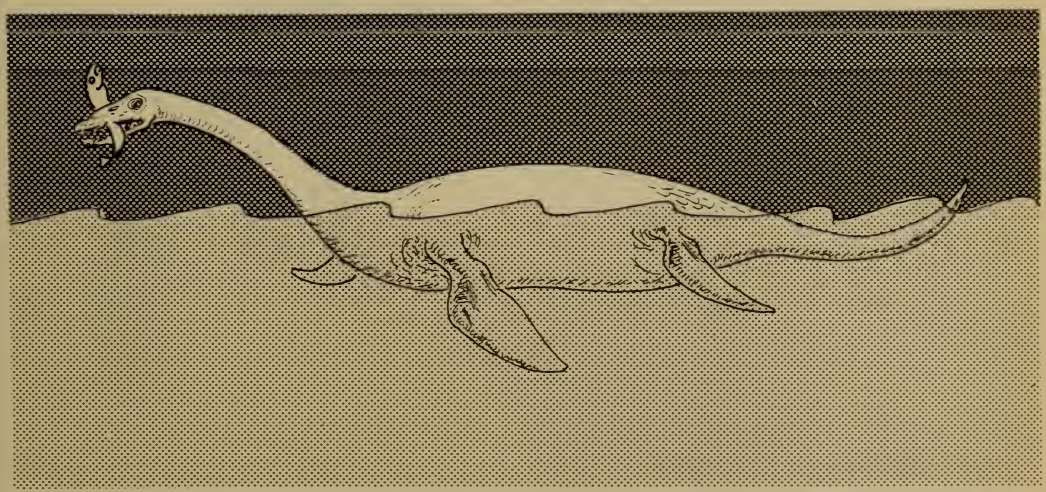
Ichthyosaurs first appeared in the Triassic period and became extinct at the end of the Cretaceous. They were like our modern dolphins in appearance, although they were reptiles and the dolphin is a mammal. They had streamlined bodies, and four strong paddles for

Illus. 68 The ichthyosaur was Monarch of the Jurassic seas. Compare this artist's reconstruction with a photograph of a modern-day dolphin. (Remember, though: dolphins seldom exceed 14 feet.)

smooth and rapid movement in the water (see Illus. 68). These paddles were not the delicate fins of fish but limbs of bone and muscle. Female fossils of these large reptiles are sometimes found with small ichthyosaurs inside them. This strongly suggests that the young were born as babies resembling the adult and were not hatched out like a chicken is from its egg. The female ichthyosaur gave live birth to her young at sea and did not lay eggs in the sand as many other marine reptiles do.

In America, the most frequently encountered Mesozoic sea reptiles are the:

Plesiosaurus ("near-lizard"): sometimes as long as 40 feet; fond of Kansas. (See Illus. 69.)



Illus. 69 The plesiosaur was another thriving inhabitant of Jurassic seas. With its broad turtlelike body and paddlelike flippers, however, it was not nearly so well adapted for swimming as the ichthyosaurs or the mososaurs. The neck was serpentlike and almost twice as long as the plesiosaur's body. This agile neck must have been a great help in catching unwary fish.

Ichthyosaurus ("fish-lizard"): usually 10 feet although some grew to be 30 feet; fond of Nevada (Nevada State Ichthyosaur Park is full of their *complete* skeletons).

Elasmosaurus ("plate-lizard"): from 20 to 41 feet long; fond of Kansas and New Jersey.

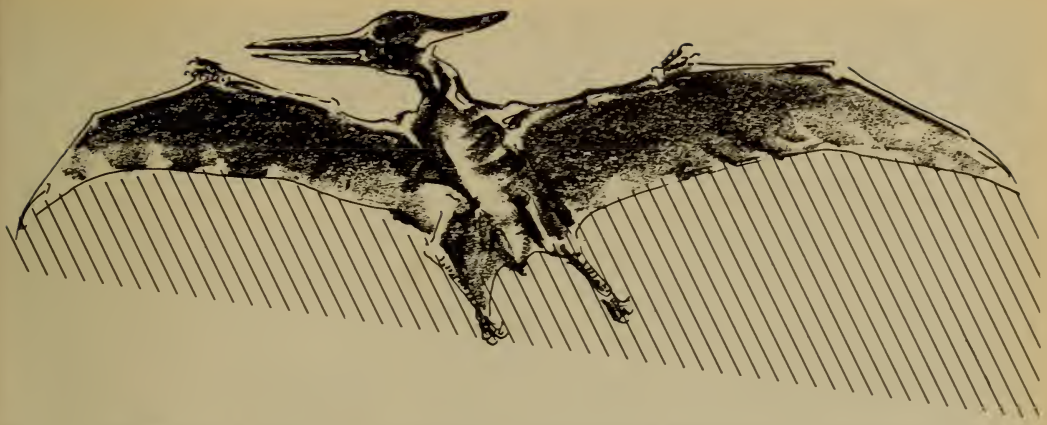
Mosasaurus ("River-Meuse lizard"): usually 30 feet long; fond of Kansas, but abundantly distributed in many parts of the American West.

The Earliest Bird

THE FOSSIL SKELETON of the little bird in Illus. 70 is more important to paleontologists than a dozen dinosaurs. Moreover, the *Archaeopteryx* is a particularly rare and vital fossil. For it shows that there is a link between reptiles and birds in the succession of life. Unfortunately, only three specimens have been found in all the world.

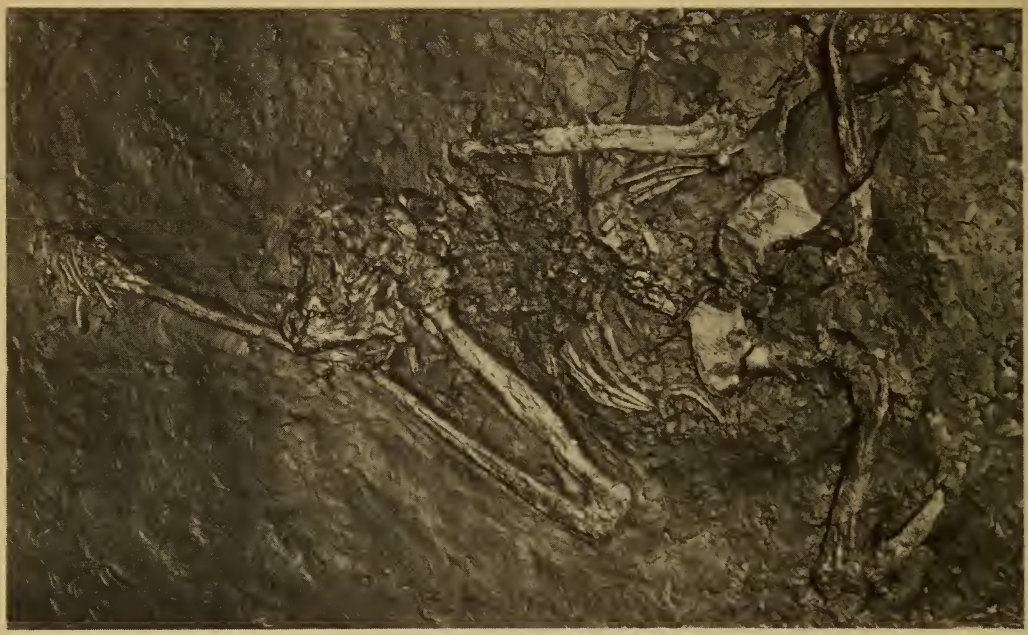
These earliest of birds had a reptilian bone structure, the skull being set with *teeth* and a backbone, as you can see from Illus. 70, extending into a long bony tail. But these ancient birds were also completely fledged. (That is, they had enough feathers to fly with.) And by comparing the bone structures of the *Archaeopteryx* with Mesozoic reptiles, we know that its feathers evolved from reptile scales.

Illus. 70 The Archaeopteryx lithographica. This pioneering Jurassic bird was only 250 mm long! Its fossilized feathers prove it was warm-blooded.



Illus. 71 The Pteranodon was one of the "winged-lizards" or flying reptiles of Cretaceous times. Their wings were covered with skin, not feathers; and these creatures were cold-blooded. Pteranodon skulls measuring 30 inches are frequently found, and the wing-span is easily estimated at 25 feet. These enormous batlike wings were held up by greatly elongated fourth fingers.

Not a single *Archaeopteryx* has been discovered in America. The earliest true birds we can boast of are Kansas' many *Hesperornis* fossils—and these birds could not fly, as Part III will tell you. The huge *Pteranodon* creature in Illus. 71, for all its flying power, was a flesh-eating reptile closely related to the dinosaur and *not* a bird. Hundreds of *Pteranodon* skeletons have been recovered from western Kansas and at least one fully restored skeleton is housed in the American Museum of Natural History.



Illus. 72 Ten million years ago an Oreopithecus died here in what is now an Italian coal mine. Since apes are forest creatures, we know that the site of this mine was once a Pliocene forest.

The Primates and Man

THERE IS SOMETHING DRAMATIC and appealing in the fossil skeleton in Illus. 72. The sprawling pose suggests a recent human tragedy instead of a remote and impersonal link with the past. The bones even look human! Yet they are the remains of an *Oreopithecus*: the "mountain ape" (so named because he was first found in a mountain). The fossil here is known to be from Pliocene times. That would make him about ten million years old—a much earlier primate than any known human remains. (The name "Primate" was given to men, monkeys, lemurs, and great apes to indicate that scientists believe them to be first in importance among the mammals.)

The striking likeness of this *Oreopithecus* skeleton to human bones—especially those of the skull—first suggested a link with Man. But opinion is now against this. The ape is not our direct ancestor; he is a distant cousin. However, the fossil remains of primates are so scanty that we still do not have the full story.

Evolution of the Primates

In Mesozoic times, some primitive mammals of the forest clawed their way

up the tree trunks to live in safety among the branches. They fed on insects and tender leaves and shoots and adapted their limbs for climbing and swinging among the branches. Thus, from the two legs and feet nearest their heads, they developed powerful arms and grasping hands. Then, too, their senses of hearing, smell and sight sharpened. In fact, the whole pace of life quickened with these intelligent little mammals. (All this is in contrast with the awkward, small-brained reptiles, then the dominant race of the Mesozoic Era!) From these first mammals came the PRIMATES.

Evolution of Man

Fossils of land animals are less common than sea-life fossils, and Primate remains seem to be the hardest of all to find. Nevertheless, the fragmentary remains of early man—his skull, teeth, and parts of the long bones—have been carefully collected, studied, and compared. From this, we get some record of Man's extinct "uncles" and of what Man himself was like before written history began.

Early manlike apes (but much younger than the *Oreopithecus*) left the forests to hunt the animals of the open grasslands. These PITHECANTHROPOIDS lived in caves. Moreover, they stood erect and their legs and feet were strong for running.

Skulls and bones discovered as fossils in China and Japan have been classified as true early men. They are *Sinanthropus pekinensis* (Peking Man) and *Pithecanthropus erectus* (Java Man). Because of these finds, scientists believed for long years that man originated in Asia. More recently though (since 1925), fossil skulls of manlike creatures have been found in Africa.

Finally, in 1959 and the early 60's, Dr. Louis Leakey discovered many bones and skulls of what appear to be the oldest true men. These were dug up in Tanzania—(perhaps you have already heard of the famous Olduvai Gorge)—and are $1\frac{3}{4}$ million years old. One of these people was a 12-year-old child. So in just a few years, many scientists changed their opinions and now believe that East Africa was man's first home. We usually call these great-uncles of Man "The Nutcracker Men" because of their huge jaw teeth. Dr. Leakey has given them the scientific name *Zinjanthropus*.

Illus. 73 Fossil evidence has made it possible for us to reconstruct Neanderthal Man's appearance quite accurately. He looked like this.

Illus. 74 Cro-Magnon Man (above) has been established as our common ancestor. Even the American Indians, immigrating to the Western continents by way of the Siberian–Alaskan land bridge, descended from him. Cro-Magnon Man was often over 6 feet tall and he had the same size brain-cage as modern man.

In Europe, early man is represented by the Neanderthal Man, who gets his name from the valley in Germany where his bones were first unearthed in 1856. Many more remains of the Neanderthal people have been found since 1856—many of them females. In fact, we have enough fossil evidence to know that these people lived in family groups and that they were stocky in build, with low brows and strong jaws (see Illus. 73). We know, too, that they used simple flint tools and hunted the Pleistocene animals for food and skin-clothing.

Fossil history shows us that the Neanderthals dwindled in the last great Ice Age of the Pleistocene Epoch. They were replaced by a new human type whom we recognize as modern man: *Homo sapiens*. The first evidence of this new race was found in a cave at Cro-Magnon in France. Here, five skeletons were preserved, and we can date them as being approximately 30,000 years old. All fossil evidence seems to tell us that Cro-Magnon Man (Illus. 74) is our ancestor, and he seems to be European in origin.

PART II: HOW TO COLLECT

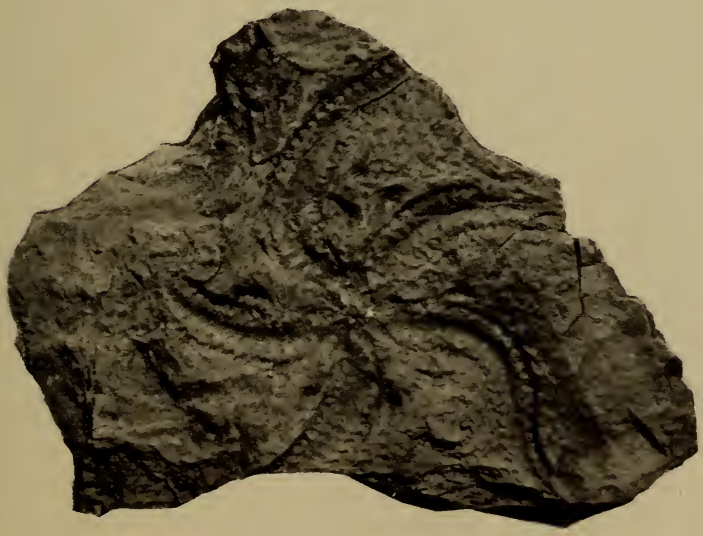
Marine Fossils

Illus. 75 This shale has perfectly preserved a Jurassic ammonite of the Harpoceras genus. Also some small Inoceramus shells (pelecypods).

MOST OF THE FOSSILS you collect will be of small sea animals, such as corals, starfish, sea urchins and shellfish. These are plentiful because conditions in the sea favored their preservation. As a blanket is laid on a bed, so layers of sand gradually settled in the water, covering the dead animals as they lay on the sea bed. The layers of rocks formed in this way are rightly called "beds."

Erosion and Sedimentation

Glaciers carve lakes and scoop rocks out of mountains. Wind, rain and frost wear down the highlands. Such work by these natural forces is called EROSION,



Illus. 76 This is sandstone that has retained the impression (cast) of an Ophioderma starfish since Jurassic times. Compare this fossil with Illus. 52B.

and the broken rock material is borne away by river and flood to the sea. Here the pebbles and sand, carried as sediment in the water, settle down on the sea floor. Rock beds are slowly built up by this process of SEDIMENTATION to become SANDSTONE, which is known as a SEDIMENTARY rock. Other sedimentary rocks, CHALK and LIMESTONE, are formed by sediments made from the limy remains of tiny sea creatures. Fine mud may be deposited as CLAY and SHALE in deep water, or in deltas and slow-moving rivers.

Since all these rocks were formed under water, they contain many kinds of ancient life. Illus. 75 and 76 are examples of sedimentary rocks containing fossils. You should collect specimens of these rocks and many other types so that you can learn to recognize the feel of them. Some are rough to the touch, and others are smooth and greasy.

Some shales are black, while chalk is white or cream-colored. Test your rock samples for hardness too: scratch them with a fingernail. Sandstone will wear your nail down, while a soft rock will show the scratch mark.

Field Work

FUN WITH FOSSILS starts when you know enough to lay this book aside and make your first trip in search of fossils. You will learn more about them in one day's work among the rocks than from any number of books. But you do need to know where to look for fossils and you must be able to identify them. So plan your fossil hunt beforehand: study a geological map, look over handbooks of your area at your local library or museum, as well as Part III of this book, and make notes from them in your field book. Finally, mark important fossil sites on your own map.

You will find most of your fossils in the sedimentary rocks exposed at cliffs and gullies and at road and railroad cuts. Take an adult with you whenever you are going near a busy highway or steep cliff. And always ask permission of the owner before you go fossil hunting on private land.

Equipment

You will need a canvas "bookbag" or a knapsack. In it, put a heavy geological hammer and a steel chisel. Other necessary items are your geological map, a compass and a pocket-sized magnifying glass, a penknife and a ballpoint pen. Your fossil-hunting knapsack should also contain newspaper and either cartons or cellophane bags to hold your

Illus. 77 Maps, field book, ballpoint pen, steel chisel, magnifying glass, penknife, rock etcher (steel-pointed scriber), labels and a geological hammer all belong in your field pack. Remember though, goggle-shaped sunglasses do a much better job of protecting your eyes from rock chips than the type shown here.

specimens. Include tie-on and stick-on labels so that you can record your fossils by genus and species name. It is especially important that you take along goggle-shaped sunglasses or some kind of eye shield to protect your eyes from rock splinters.

Set out a page of your field book like this:

LOCATION	MAP REFERENCE	DATE
SYSTEM	BEDS	
SPECIMENS	EXTRACTED FROM	
1		
2		
3		
4		

Record your finds carefully, for unless you know exactly what place and rock bed your fossil came from, it is scientifically useless to you.

When you reach the spot you have decided to search, look for fossils that are exposed on the rock surface and decide on how they can be taken out without damage. Extracting fossils needs care and patience, but you will soon learn the knack.

Soft rocks and delicate shells call for a light touch, so very often you will have to cut out a sizable piece of rock surrounding a fossil in order not to break it. On the other hand, some fossils in hard rock jump out cleanly when you strike the rock surface with a sharp blow of the hammer.

Record each good specimen, label it, and wrap it in newspaper. Discard poor specimens.

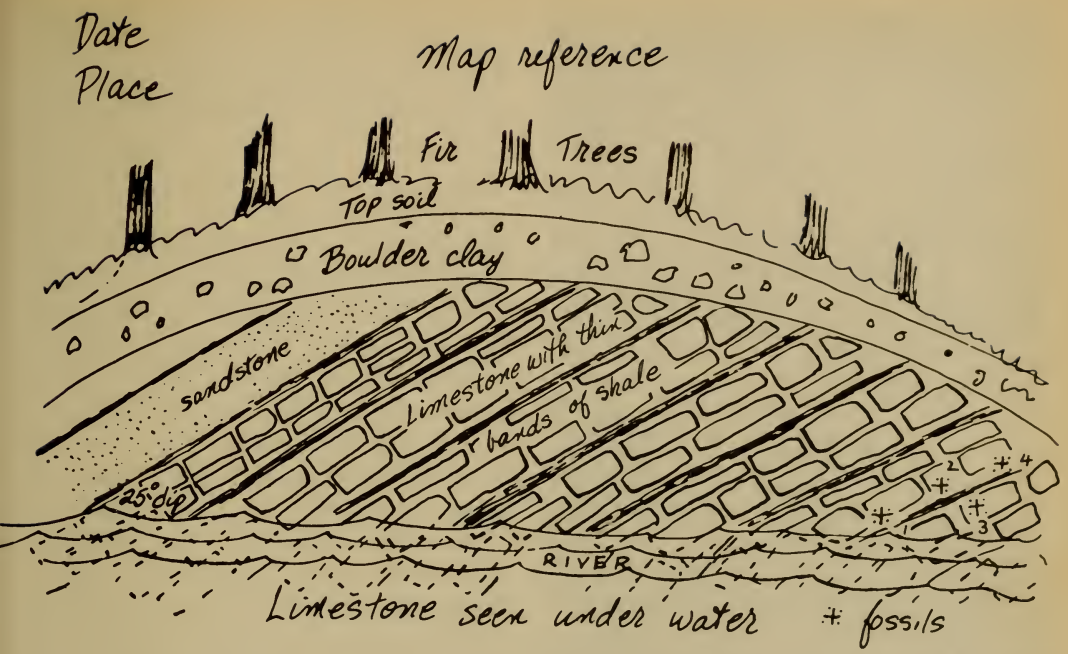
Field Sketching

A GEOLOGICAL MAP of your community is different from a surface map that shows land features you may know quite well. Your own sketches (they should look like the sample shown in Illus. 78) will help you to follow the arrangement of rocks on the store-bought geological map, if you use the special symbols that represent the rocks. You can follow these symbols from Illus. 78A: sandstone is shown by dots, limestone by rectangular boxes, and clay or shale by close, horizontal lines.

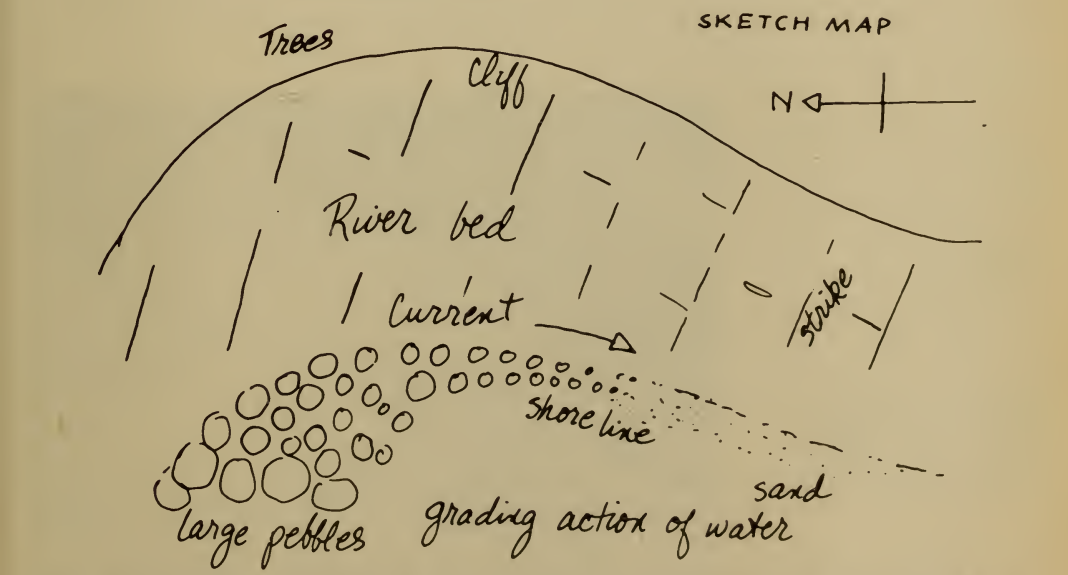
Illus. 78B is a sketch of a river bank that has a low cliff exposure of limestone. The fossil hunter has written "Date," "Place," and "Map reference" in at the top. He has used two curves to show the topsoil and a few rough strokes to indicate the trunks of fir trees. A lower curved line marks the depth of a clay deposit, and under this is the limestone formation of his locality, carefully marked with joints. (Illus. 79 shows you how limestone joints look in "real life.")

The drawing carefully shows how the rock beds dip to the north. Each fossil find is marked with a cross and numbered to correspond with the specimen that was taken there. The river level is drawn with a few wavy lines.

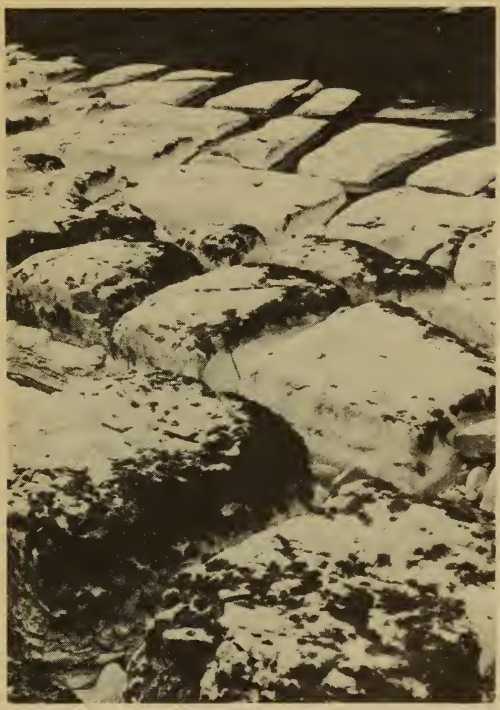
This fossil hunter then went on to



Illus. 78A. Sketch from a fossil hunter's field book, with the various kinds of rock keyed in.



Illus. 78B. The fossil hunter thought the effect of the river-bend important enough to record.



Illus. 79 It is obvious from this photograph of ordinary limestone joints why rectangular boxes have been chosen as the geological symbol for limestone beds.

sketch the direction (downgrade) of the river current (the lower part of Illus. 78), so that he will remember, in the future, that the larger rocks and stones are caught on the river bend, while smaller pebbles are carried farther downstream.

You will understand the need for notes and sketches like these when you return home with your first bagful of fossils. For the next step is to sort them and recall where you found them. Remember, a fossil is always interesting, but it is useless in piecing together the earth-history of your neighborhood unless you know exactly where each one came from.

Illus. 80 Two fossil hunters joined efforts to uncover this 28-mm Neptunea contraria shell.

Operation *Neptunea contraria*

The boy and girl in Illus. 80 prepared for their fossil-hunting adventure by studying a book on Cenozoic fossils because they live in an area where rocks of that era are common. From that library book, they knew exactly what to look for and were able to decide on exactly what they were especially interested in: a *Neptunea contraria* because its shell spirals in a direction contrary to most gastropod coils. They succeeded. For here you see them unearthing a Pleistocene *Neptunea contraria* from a soft, crumbly rock where it had lain, undisturbed, for a million years.

The method of extracting the fossil was simple. They scraped the loose sand away with a small garden trowel until the fossil was fully exposed. Then they lifted it out of the main mass by hand.

Preparing Specimens

YOU CAN MAKE a "preparation board" (see Illus. 81) to clean and develop your specimens on, from just a few pieces of wood. Use a 1-inch-thick board about 9¾ inches square as your base. Cut out two pieces of wood ¾-inch thick and 1½ inches wide by 9¾ inches long. Screw one of these under the base and the other on top to make rails. Add two slim, short, turnable pieces of wood ("turn-buttons") screwed onto the top rail (see illustration), and your preparation board is finished!

Flat slabs of rock can be held on the board by the turn-buttons. For large, irregular rock samples, use a C clamp. Once you have your specimen firmly held on the board, you can begin the work of cleaning. Use needles, your penknife, and a small jeweler's chisel to chip away the matrix or outside rock. Take off small flakes, at *right angles* to the fossil itself, so that you don't scratch the fossil. If you are working with small fragile shells and plants, leave them exposed on the rock slab after you have cleaned them.

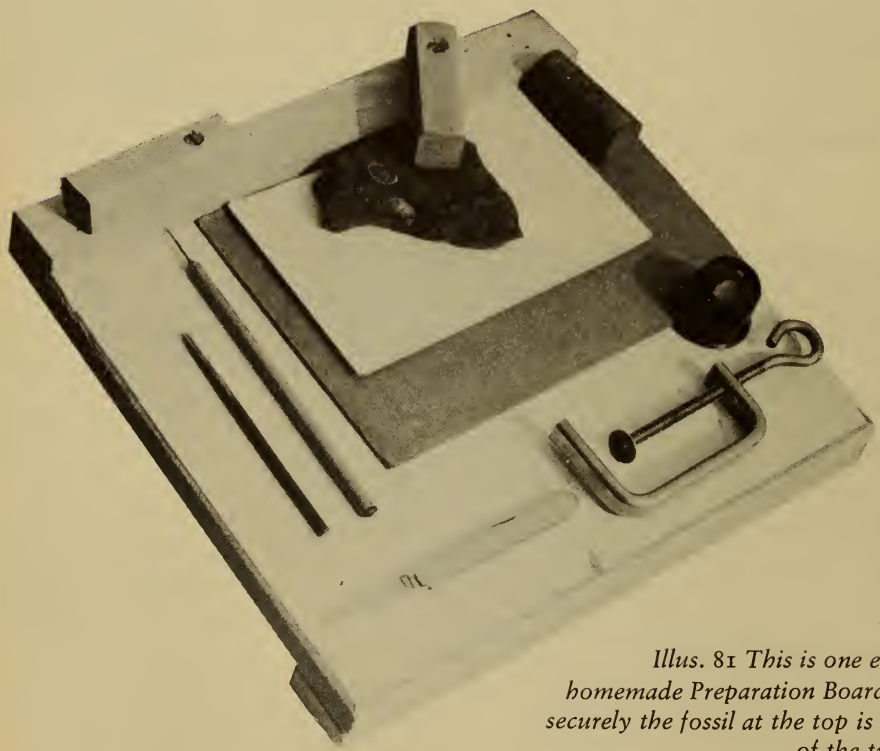
To release a fossil from a hard matrix, you may have to drill holes around it and *only then* cut it clean. Since freshly cut

rock hardens quickly in the open air, you should do your rough trimming as soon as possible after you have collected your fossils.

You can use weak acids to dissolve and loosen limy rocks. Acetic acid and kitchen vinegar are especially suitable. The owner of the *Pleurotomaria* in Illus. 82 cleaned it by first chipping away the rock matrix and then coating the exposed shell with a wax film. Finally, after many acid baths to get the rock fragments out of the shell crevices, the collector scrubbed his *Pleurotomaria* in hot, soapy water with an old toothbrush.

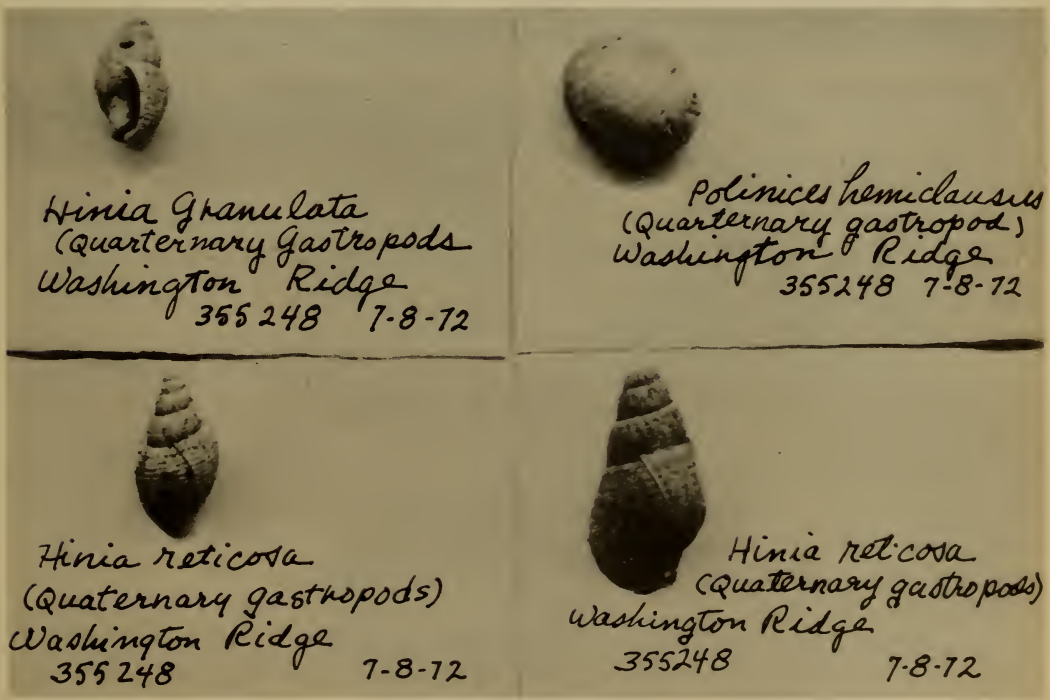
Fossil shells that you take cleanly from soft beds need little preparation beyond dusting off the loose dirt. Before you do this though, examine your specimen under a magnifying glass, for it may be encrusted with bryozoa (wanted at other times, but not now). Or you may find the cast of a *Serpula* worm in it and you certainly don't want to bring one of these live creatures into the house.

If you should happen to break a prize fossil, you can repair it with Elmer's Glue. When you have finished cleaning your fossils, mount them on cardboard and display them. Each specimen should be labeled according to time unit, genus and species—maybe even its class (see Phylum in the glossary).



Illus. 81 *This is one example of a homemade Preparation Board. Note how securely the fossil at the top is held by one of the turn-buttons.*

Illus. 82 Sometimes a fossil, cleaned and polished, can hardly be recognized as the same grime-coated relic you took out of the earth. Here, the before and after states of a 55-mm Pleurotomaria anglica. This sea-snail shell is from Jurassic times.



Illus. 83 Here, the fossil hunter has chosen to label his Cenozoic shells by periods instead of by epochs. Every fossil in your collection will be rewarding if you label it in a professional manner.

Photography

Illus. 84 To get a general view of a fossil-rich locality, a young paleontologist had to take this long-range photograph.

A CAMERA is a valuable tool in enjoying fossils. (In fact, only by photography can you collect the dinosaur tracks abundant in so many parts of America.) When you are out collecting, you can take pictures of the fossiliferous rocks you don't have time to search through. And when you get home, you can make prints and slides of the specimens you did pick up.

Record the places you visit—a beach maybe—by first taking a long shot (a general view) of the landscape. Illus. 84 is a good example of this kind of snapshot. Next, take a medium-range shot when you are a few yards away. This will record the structure and the nature of the rock faces. Finally you can photograph the fossils at close range (Illus. 85) just before you extract them. These close-ups are important because sometimes you will not be able to extract the fossil you want. The giant ammonite in Illus. 85, for instance, could not be collected because it was too big to be removed without harming it. To give you some idea of its size, a hammer has been placed alongside it in the photograph. The ammonite is, in fact, 19½ inches in diameter.

Fossils also make good subjects for your home-photography hobby. You can photograph them in either daylight or artificial light, but make sure your fossil is well lit on all sides. This will prevent heavy black shadows which might give a totally wrong effect to your fossil.

With a combination of good lighting and good focusing, you will get sharp and detailed negatives. You can enlarge your prints to the exact size of the fossil. At this size, every detail will stand out (see Illus. 86).

Illus. 85 It is always a good idea to take a close-up photograph of a particularly important or desirable fossil before you extract it. In this case, the giant ammonite proved to be too large and fragile to remove.

Illus. 86 Here, a young paleontologist–photographer has captured the exact texture of this Cardinia shell. Always print your pictures the same size as your fossil. (Here, 85 mm.)

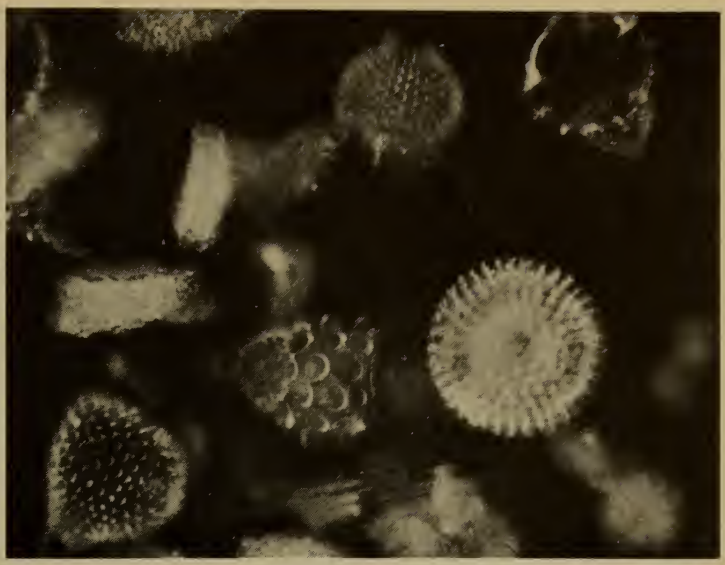
It is a good idea, too, to use COLOR-POSITIVE film. Then the films you get will be slides that you can show on a screen. You can use such slides to illustrate any talks you might want to give on fossils—either in school or at gatherings of your family or friends. In making prints or slides, select your best fossil specimens and shoot them against a light neutral background, to give value to the subtle tones of the fossils.

Microfossils

The fossil in Illus. 58 is just one type of microfossil. There are many other forms of animal and plant life so tiny that you usually need some kind of magnifying glass to see them. For this reason, they are often put under a microscope. Most of the animal microfossils are protozoa. The *Foraminifera* and *Radiolaria* protozoa manage to form shells in wonderful shapes and patterns (Illus. 87 and 88). With their delicate design and extraordinarily varied shapes, these microfossils are a particularly exciting subject for photography.

To take pictures of these ancient relics of the miniature world, you will need both a microscope and a camera. (You probably will need a strong magnifying glass to locate them in the first place.) If your camera is a miniature one, buy yourself one of those special devices called "micro-adapters" which permit you to yoke your camera onto the microscope's eyepiece. Remove the

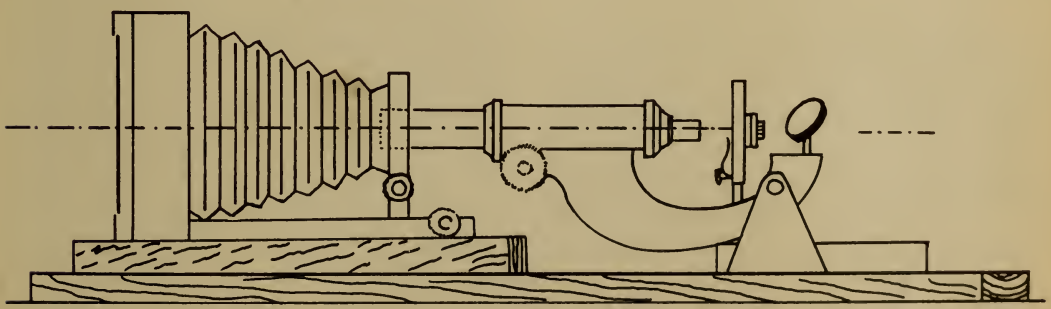
Illus. 87 This enlarged photograph (photomicrograph) gives you an idea of the myriad shell-shapes that Foraminfera can produce. Note how some shells are coiled like ammonoids.



Illus. 88 Another photomicrograph: This one, of Radiolaria shells. The Radiolaria protozoa are known for the silica content of their shells and their intricate exquisite tracery.

camera lens first and then screw the micro-adapter into its place. And you can also get good results with a camera that has extending bellows plus the important ground-glass focusing screen. Illus. 89 shows you this arrangement and also how to set it up on a board.

You should make SLIDES out of your microfossil specimens before you photograph them. That is, mount them on glass about 26 mm wide and 76 mm long. Cover them with an extremely thin piece of glass the same size. You can possibly obtain some microfossils themselves by scraping out slices of *natural* chalk or limestone and adding a little water. Then put this paste between your two pieces of glass.



Illus. 89 This bellows camera contains a ground-glass focusing screen for taking better photomicrographs. Take the lens off all cameras before you mount it on any microscope eyepiece.

Illus. 90 Here, a small museum is displaying some cephalopod shells easily found in the area—and local fossil-enthusiasts are taking full advantage of the exhibition! Can you recognize one of these shells as an Arisphinctes maximus?

Museum Study

YOUR OWN FIELD WORK will take first place in your new hobby, and museum study comes next. In museums you can see fossils that have already been cleaned and classified and are properly described in their showcases. In this way you can learn to recognize the fossils you are especially interested in finding.

Maybe you don't live in a big city where dinosaur and other spectacular animal skeletons are displayed. Nevertheless, your town museum probably has a geological section where local fossils are on view. These may be of even more interest to you, as you can use them to become an expert on the rocks and fossils of your own district. Moreover, the museum exhibits will help you to learn how to classify and label the fossils in your own collection. Try to get to every important museum exhibition and to learn when the displays are

being changed. Your town museum will probably also have a collection of geological maps and handbooks that you should consult before every field trip into a fossil area you have not covered before.

When you are certain that you have found a rare specimen, report it at once to your local museum, Often, too, you can ask their help in identifying a fossil you can't figure out.

Your Fossil Club

MANY FOSSIL COLLECTORS—young and old alike— find it helpful to belong to clubs that plan and organize fossil outings. In this way, everyone has a chance to learn quickly, and by actual *doing,* how to find and identify fossils. Often these clubs will provide you with the guidance of an adult who knows fossils well. Your local museum can give you information about the local fossil societies you can join to do organized field work. So can the many geological information services listed in Part III. Or maybe you and some interested friends can form your own club on a school or neighborhood basis. If so, here are some rules you should follow:

1. Plan your work beforehand and obtain as much information as possible about the area you will be searching.

2. Wear clothes that are suitable for the climate and ruggedness of the area and carry food along with you in the knapsack that holds your fossil-taking equipment.

3. If you are going into remote country, leave information of your route with someone at home or at headquarters of your fossil club.

4. Do not expose yourself or others to danger—at the sea coast watch the tides and beware of dangerous cliffs; when you are searching near rivers and lakes, acquaint yourself with their currents; do not go into caves alone and if your fossil site is a railroad cut, be on the watch for unexpected or off-schedule trains.

5. Protect all wildlife in the area.

6. Observe the same personal code of conduct you would follow in your own home or neighborhood. That is,

(a) don't be a litterbug;

(b) ask permission before you go onto private property.

Finally, report all important finds to your local museum.

Fossil Hunter or Paleontologist?

TWENTY DIFFERENT SPECIES of ammonoids are shown and named in this book, but these are only a few of the many hundreds known and classified—and the many not yet identified! This profusion of species is to be found in all the shellfish classes and among corals, fossil plants, and most forms of ancient life. With all this material at hand, there is a lot of work to be done by both individuals and groups working in the spirit of scientific inquiry—quite possibly by you.

When you search for fossils you are a fossil hunter. That is plenty of fun in itself. But when you search for knowledge about the fossils you are recovering, you are then a PALEONTOLOGIST with a good chance of filling in some of the story about what happened on earth before man arrived.

Part of your research work can be simply measuring and counting. For instance, how many different species of fossils are to be found in a square yard of rock surface? Which is the commonest fossil found in that rock? And what is the average size of that species, measured in millimeters?

Not only these questions, but endless more are there to be answered—perhaps by you.

Illus. 91 You will look something like this when you put down this book and go seriously out into the field. Always take a companion with you, however, and sort your finds intelligently.

PART III: WHERE TO FIND THEM

THIS IS A BOOK you will want to keep and study for a large part of your life. To make it even more of a working manual, we present this state-by-state index of the best fossil locations in the U.S. Moreover, you will find here that the fossil-rich counties in each state are catalogued according to the period in which they specialize.

While this appendix is written in adult terms, you should be able to understand them after having read Parts I and II of this book.

If you scan the fossil descriptions of a few states, you will realize that warnings are given about searching alone. This is important! You should prepare your digging expeditions with the advice of an adult—an expert preferably—and take one along with you whenever possible. Maybe even your parents would like to join in the hunt!

Illus. 92 Fossil shrimps are not the easiest specimens to come by, but several states offer them. Here a Teallocaris shrimp from a species that thrived in Mississippian–Pennsylvanian times (35 mm actual size).

Alabama

Alabama is a well-endowed, fossil-hunter's delight —one of the most fossiliferous areas in the United States. A whole treasurechestful of fossils can be yours, if you search for them almost anywhere in the state. Nevertheless, two areas stand out: the Mineral Region in the northeast and the Agricultural Region in the southwest. The Mineral Region in particular has an abundant supply of fossils that have been petrified into rocks.

Central Alabama also has many fossils, and large areas of perfectly preserved mollusk shells are to be found there. Brachiopods and ancient clams are in Butler County; the best trilobites in the United States are in Cherokee County; and masses of corals, large and well-preserved, are in Franklin County—just a few examples of Alabama's supply of fossils.

For additional information and locality maps, write to: Geological Survey of Alabama, University of Alabama, University, Ala. 35233.

Alaska

Peculiarly enough, often-harsh Alaska can be made to yield up a wealth of fossils—although much of it consists of amber and petrified wood. For one thing, Alaska's vast Central Plateau (east and north of the Pacific Mountain System) consists of the best preserver of all: the *permanently* frozen subsoil called "permafrost." Mollusks and brachiopods abound in the Pennsylvanian limestone deposits of this area, while porcupine fossils can be found in limestone exposures of the Devonian Period. In the peat beds of the Fairbanks region, you can find bison, mammoth, and horse relics, as well as stone records of saber-toothed cats—all dating from the more recent Pleistocene Period.

The Arctic tundra of this state offers fossils of widely varying age: from rare and extinct goniatites (overspecialized mollusks) of the Mississippian Period to fish remains as late as the Jurassic. In the many river beds of the tundra, amber is plentiful.

The Seward Peninsula, too, is a delight for amber-seekers. Nome and its environs provide animal remains and leaf imprints from as far back as the Silurian Period, while masses of coral and petrified bryozoa colonies are to be found in the Cape Lisburne area.

Don't search southwestern Alaska for animal fossils. However, you will find agates and petrified wood in abundance there. The southeastern portion of the state, heavily indented with fjords and carrying the burden of massive glaciers, provides the oldest fossils of all: Ordovician bone relics on the west side of the Alaska Range.

More detailed information and pertinent maps are available from the Department of Mines, University of Alaska, College, Alas. 99701; also from: U.S. Geological Survey, 210 E.F. Glover Building, Anchorage, Alas. 99500.

A fossil-hunt in Alaska is all the more rewarding because until the recent opening of the Alcan Highway, getting at these ancient bones and amber was very difficult. Therefore the supply remains relatively untapped.

Arizona

Arizona is best known for its Mesozoic vertebrate fossils and, like Alaska, for its petrified wood. In the northern, plateau counties of the state you will find sharks' teeth, camels' teeth, elephant tusks, and dinosaur tracks, while the Painted Desert and Petrified Forest are spectacular monuments to the wonders wrought on Arizona's rock formations during Triassic times. Here, too, is the Grand Canyon, whose walls (Triassic limestone and Permian sandstone) contain a wealth of brachiopods, trilobites, corals, and other fossilized water animals. Most of these, however, can unfortunately be retrieved only in fragments.

The mountainous regions of Arizona again yield mostly corals, brachiopods, and other fossilized water animals. However, they range in age from the early years of the Mississippian Period to the Middle Cambrian. Pima County, which holds Tucson, is another mountainous district. This one, however, contains dinosaur-bone fragments, fish and turtle remains, and a good many Permian relics besides the usual supply of Mississippian water creatures.

The third physical division of Arizona, its desert areas, is happy hunting ground for rodent teeth, brachiopods, and coral. Here the predominating ages are Upper Cambrian and Permian. The one thing Arizona seems to lack is Cenozoic fossils. For this state has been able to preserve only remarkably little of the organic life it supported during the first 69 million years of the geologic era in which we live. The Navajo Reservation—especially its northeast reaches—is practically the only place you can pick up the bones of Pleistocene camels and bison.

For maps and more detailed information, write either: Geology Department or The Arizona Bureau of Mines, both at the University of Arizona, Tucson, Ariz. 85721.

Arkansas

Arkansas is practically half coastal plain and half interior highland. The 52 per cent of its area which is Coastal (Mississippi alluvial) Plain ranges from early-Cretaceous to Quaternary-Period land formations. Here, in counties such as Cleveland, Grant, and Little River, mollusks are the things to look for. Also abundant are sea urchins and fossil plants. Almost as plentiful as the mollusks themselves (which are the

pride of fossil-hunters in the coastal-plain region) are the *molds* of the ancient mollusks. Drainage ditches throughout this region are a good place to find these molds as well as to collect (or photograph) the impressions left, epochs ago, by long-dead grasses and plants.

The other 48 per cent of Arkansas (the Interior Highland) comprises land formed during the Paleozoic Era with a few Cretaceous outliers. Here, Boone County boasts dwarf gastropods, mussels, and cephalopods as well as a formation of Upper Cambrian marble chock-full of algae fossils. Ordovician and Silurian jellyfish molds are in the Interior Highland; and in many counties you can find fishes' teeth. For additional information and locality maps, write: Director of Geology, Arkansas Resources and Development Commission, Little Rock, Ark.; also the Arkansas Geological and Conservation Commission, 446 State Capitol, Little Rock, Ark. 72200.

California

The vast expanse of exposed fossil-rich rocks along the Pacific Coast make California one of the best states to go fossil-hunting in. Moreover, the complicated geological history of the "Golden State" means that every new highway cut through the topmost soil layers, every new building excavation or railroad trestle forced "dormant" fossils out—and sometimes into the collector's eager hands.

The Pacific Coast rock outcrops and the rock formations of California's interior basins date from merely Cenozoic times. Here you will find the remains of extinct beavers, geese, camels, and three-toed horses—especially around Berkeley. The foothills of Contra Costa County yield up Pliocene mastodons, dogs, hornless antelope, camels, and pig-deer. Los Angeles County, for all its urban development, is another fossil-rich Pliocene outcrop. Miocene and Pleistocene fossilized mammals can also be found here. San Diego County is a fine place to go hunting sharks' teeth buried in Pleistocene rocks. Santa Barbara County has both fish and whale remnants for the taking. The many caves of Shasta County still hoard their treasure of fossilized Pleistocene bears and mountain goats. (But no experienced "outdoorser" ever goes cave-exploring alone!)

Other areas of California range from Paleozoic to all three periods of the Mesozoic Era. The collector avid for ammonoids is particularly lucky. Indeed, California has at least 600 localities where fossils of these highly interesting but extinct mollusks can be easily found. Among the most popular are the hills west of the San Joaquin Valley, the region southwest of the Sacramento Valley, various points around San Francisco Bay, and the Santa Ana, Santa Monica, and

Illus. 93 California is one of the states rich in plant fossils. Here, a shred of fossilized club moss.

Santa Inez Mountain Ranges. All these areas have Mesozoic rocks from the Cretaceous Period. For Triassic coral, look again to the county housing the famous Shasta caves, while the creeks of San Luis Obispo County will yield up Jurassic water creatures.

The immense Paleozoic Era is represented by fossil starfish and brachiopods that are plentiful in the mountain gulches of Siskiyou County. These 370 million years are also represented by the trilobites and marine-plant fossils of San Bernardino County. Here the tiny animals and sea-plant relics go as far back as the Lower Cambrian Period! West of the Cascade Range are Silurian shellfish and bryozoa.

The so-called forams—tiny one-celled animals who nevertheless have shells, rather huge shells in fact for the size of the organism inside—are plentiful in California's oil fields, but you will have to take a magnifying glass along with you, as these fascinating, encased protozoa average only one tenth of an inch.

Finally there are the great desert stretches of southeastern California—notably the Mojave. Here the Paleozoic sands offer a variety from Ordovician to Devonian life. Most interesting of all though, is the fact that these particular fossils have been preserved by dessication rather than by replacement of the original structure with minerals or preservation by mineral-coating of the original structure. On the other hand: in the beds of what were once this harsh desert's lakes, you will find insects, spiders, and other arthropods so perfectly preserved by silicon replacement that you can still see their fragile legs and even the body hairs.

One is no longer allowed to collect fossilized bones from the La Brea tar pits. But if you live in southwestern California and are at all interested in bygone forms of life, it is a must to visit these abysses where giant, but sluggish, prehistoric animals were trapped for an eternity as oil under the water slowly turned into sticky asphalt. Besides, you can see the concrete life-sized statues of the Pleistocene beasts whose skeletons were retrieved here, even if you can't do any gathering up of your own. The bones themselves

have recently been mounted and are now on display in the Los Angeles County Museum, Exposition Park.

For additional information and locality maps, write: California Division of Mines, Department of Natural Resources, Ferry Building, San Francisco, Calif.; or: U.S. Geological Survey, 4 Homewood Place, Menlo Park, Calif.; or: U.S. Geological Survey, 724 Appraisers Building, San Francisco, Calif. 94111. (California, incidentally, is one of the states equipped to supply you with guidebooks and illustrations.)

Colorado

The "Centennial State" is less endowed with fossils than most of its Western neighbors because the greater part of Colorado's rocks were formed by erupting volcanoes (at the end of the Permian Period). However, a few selected spots throughout the state make fossil-hunting extraordinarily rewarding. (Some of these are even famous.) Cuttlefish, nautiluses, snails, and reptile teeth abound in the Permian sediments of Boulder County, while Chaffee and Fremont Counties are the places to go for brachiopods. Fremont also boasts a large population of excellently preserved corals.

Moreover, since Colorado is part of the Rocky Mountain Region covered by the Morrison Formation (all of its surface west of the Colorado River straight to the Utah border), dinosaur bones from the Jurassic Period are yours for the looking in certain places—in Weld and Moffat Counties, for instance. It is Mesa County, however, that is famed all over the United States for dinosaur bones of gem quality—even agatized and jasperized ones. In fact, not far from Devil's Canyon is Dinosaur Ridge, named after the gigantic beasts that once stalked the area and then littered it with their bones.

Florrissant in Teller County is one of the famous spots that represent the Cenozoic Era. Here, in lake-bed sediments, you will find Oligocene dragonflies, butterflies, horseflies—and even tsetse flies! Fossilized plants of the Oligocene Period can be found side by side with these long-dead insects in the same lake-bed sediments.

Thus, what Colorado lacks in *number* of fossil sites, it more than makes up for with the splendor of its fossil offerings. Besides this, you will find petrified wood throughout the state. And the land teems with Indian arrowheads.

For specialized information, write: The Colorado Geological Survey, 220 Museum Building, Denver, Colo. 80200; or: The U.S. Geological Survey, Denver Federal Center, Denver, Colo. 80200.

Connecticut

Connecticut is remarkable for its lack of fossil bones —with the exception of the fishbeds to be found in the Triassic sandstone of Hartford and Middlesex Counties. This lack is all the more extraordinary because the black shale exposures throughout Connecticut abound in dinosaur tracks—to the point where you can be sure that these huge creatures once had a field day in Connecticut's lovely countryside. In fact, with the aid of a camera, you can capture the actual paths, running for miles, where dinosaurs used to stroll.

Rocky Hill in Hartford County was evidently the favorite haunt of two dinosaurs, both relatively small fellows who weighed only a ton. Like most carnivorous dinosaurs, these creatures walked on only their hind legs. The identification of at least 1,000 three-toed footprints as Coelophysis tracks led the Governor of Connecticut to reserve 7½ acres around Rocky Hill as a state park.

The dinosaurs who made the largest footprints at Rocky Hill have not been identified yet. They were probably much like the Dilophosaurus of Arizona (see Illus. 65.) The footprints have been carefully preserved with a chemical, and you can easily reach this open-air museum by traveling down Highway 91 or Route 9. (Interestingly enough, if you study the "stroll" patterns at Rocky Hill Park, you will discover that Connecticut's dinosaurs, at least, were not solitary, hermit-like creatures, but sociable monsters who liked the company of their own kind.) The few places where dinosaur bones themselves can be picked up occur mainly in New Haven County.

Connecticut's Berkshire hills, coming into being during the Ordovician Period, contain mainly the relics of invertebrate sea animals. A WORD OF WARNING, however: although some of Connecticut's scarce fossils have been preserved in quarries, these are dangerous places. It is better to return from a fossil-hunting jaunt empty-handed than to put your friends' lives or your own life in jeopardy.

For more detailed information, write: the Connecticut Geological and Natural History Survey, Trinity College, Hartford, Conn. 06606.

Delaware

All but a tiny portion of Delaware consists of Atlantic Coastal Plain. Thus Cretaceous and even younger soil blankets most of the state. The best fossil sites in all of Delaware are to be found along the Delaware Canal. But like those in the rest of the Coastal Plain, they yield up almost purely Cenozoic specimens. In fact, Delaware in general is not the fossil-hunter's paradise. Nevertheless, at certain times Sussex county has surrendered fossilized bryozoa, snails and limpets, and even sharks' teeth. Along the Lewes and Rehoboth Canal, you can still pick up *Pleistocene* shells by the handful.

New Castle County's greatest fossil treasure is its oyster and crab relics—again located mostly by the

Illus. 94 Delaware, Florida, Georgia, Hawaii and North Carolina are all outstandingly rich in Cenozoic shell fossils. Here, a Clavilithes macrospira. This 80-mm gastropod is Eocene in time.

banks of its canals. By looking very hard though, you may even be able to find ammonoids—those shelled cephalopods that "went out of business" at the end of the Cretaceous Period! About 3 miles east of the Maryland border at a latitude approximating Summit Bridge are abundant deposits of fossilized earthworms!

The tiny bit of Delaware, about 10 miles wide, that does not share the Atlantic Coastal Plain with the rest of the state is part of the Piedmont Plateau. This northernmost area of the state (marked off by the Fall Line just south of Newark, Del.) is pre-Cambrian in composition. So your fossils here will be mostly invertebrate water animals with shellfish predominating.

Kent County is interesting because the town of Dover almost perfectly establishes the point in Delaware where Tertiary sediments "take over" the state from the Cretaceous soil. Even more important is the fact that here—and especially around Dover Air Force Base—you will encounter masses of "forams" (properly, Foraminifera) again: those tiny protozoa that astoundingly managed to grow a shell. The type of Foraminifera once populating the Dover area is a species that paleontologists know always live close to the surface of a body of water.

For more information, write: The Delaware Geological Survey, University of Delaware, Newark, Del. 19711.

Florida

The "Sunshine State" is another of the most fossil-rich states in America. Its special treasure is the bones and teeth of extinct species of vertebrate animals which lived during the Cenozoic Era. In fact, the oldest rocks identified in Florida go no farther back than the Oligocene Epoch! Along the Atlantic Coast—Daytona, Palm Beach, and St. Augustine to name just a few spots—you can find Pliocene shelifish as well as Pleistocene mastodons (huge extinct animals closely related to our present-day elephants), 3-toed Pleistocene horses and deer teeth. The drainage canals here are the best place to look for their bones, but you should not go searching in these areas alone. The Gulf Counties of Citrus and Levy and the interior Marion County are rich in the same type of fossil specimens as the Atlantic Coast region. But in these three counties you will find an abundance of fossilized sea urchins, shark bones, and sea cows too.

The mud bottoms of the creeks around Gainesville (Alachua County) are rich in fossilized sharks' teeth. However, you will have to sift through the silt or pebbles on the bottom of these inland waterways to get at them. Duval County in the extreme northeast of the state abounds in *molds* of Cenozoic animal life, while the area around Lake Okeechobee specializes in mollusk fossils—Hendry County alone having 20 different species of ancient clams, oysters, and mussels. De Soto County, in the same area, offers turtle remains. Polk County in central Florida would be interesting for its numerous armadillo relics alone, even if it did not have fossilized mastodons, tapirs, horses, and the antler bones of extinct deer species.

Actually, the fossil wealth of Florida defies description. So for more detailed information, write: Florida Geological Survey, Box 631, Tallahassee, Fla. 32302. And Florida, like California, is one of the states whose geological commission can provide you with an excellent guidebook.

Georgia

The "Empire State of the South" is a rather complex area, geologically. For Georgia's soil represents the Paleozoic Era, Cretaceous and Cenozoic times—and even the eons before the Paleozoic Era. The Chickamauga Valley of Georgia's Cumberland Plateau consists of a great many Ordovician-rock outcrops. Here, in counties such as Walker, Chattanooga, Catoosa and Dade, you will find an abundance of ancient brachio-

pods, bryozoa, corals, gastropods, pelecypods and even the minute ostracods (microfossil crustaceans that actually look more like clams than crabs, since their soft, unsegmented bodies are enclosed in bivalve brachiopod-resembling shells).

Traveling southeast down the state, the next geological region of Georgia is the *main* part of the Piedmont Plateau. This is the area where you will find soils that pre-date even the Paleozoic Era of our planet. Formed of material once on fire when deep within the earth and released to the surface only by volcanic activity, these now-cooled, crystalline soils have little specimens to offer. [Moreover, life during the first billion years of the earth's existence consisted of either protozoa, algae, and soft organisms that had no hard parts to be preserved or—a couple of billion years later—extremely primitive sponges and brachiopods plus rudimentary earthworms and other annelids (just as unspecialized) whose only fossil heritage to us is the impression of their ancient burrows. Thus the main fossils of these eons are simply the earth itself—especially great masses of organic limestone which are actually petrified colonies of algae that passed away even before complex life, as we know it, began in the Cambrian Period.] The Appalachian Mountains and Valley of Georgia, composed of this same pre-Paleozoic, igneous material also fall into this fossil-poor category.

The Coastal Plain lies south of an imaginary line drawn southwest from Augusta, through Midgeville and Macon, to Columbus on the Alabama border. Here the soil is much softer than the volcano-effected deposits of the Piedmont Plateau. Cenozoic fossils predominate over the Cretaceous in the Coastal Plain. However, they are not easy to reach, and most of the time you will have to take a river trip to get to them.

Quitman County is a prize place to look for fossilized sea urchins, crabs, and mollusks. Make sure you go to the spot on the right bank of the Chattahoochee River just opposite the Alabamian town of Eufaula. Cenozoic corals abound in this same county. And at Alexander's Landing on the Chattahoochee River you will find ancient fish teeth and crab claws. Crocodile remains are also available. So are turtle remains and even a few dinosaur bones.

Other good counties of the Coastal Plain area to go fossil-hunting in are: Clay (mollusks, sharks' teeth); Jones (a whole host of invertebrate animals); and Russell (prehistoric vertebrate animals, oysters, and mussels). In fact, Cenozoic mollusks, echinoderms and other forms of marine life almost monopolize the fossil resources of Georgia. One county, Decatur, has so many snail, whelk, and abalone relics that a spot near Bainbridge has even been named "Gastropod Gully."

In the Cretaceous white clay of Washington County you will find plenty of fragments of Mesozoic crabs and many pieces of other water-dwelling creatures of that era.

For a whole series of excellent and even illustrated papers devoted to the fossils and complex geology of Georgia, write: Department of Mines, Mining and Geology, 425 State Capitol Building, Atlanta, Ga. 30334.

Hawaii

Four of the twelve islands composing the state of Hawaii are barren rocks, and all twelve are volcanic rock. The islands' beaches, however, are Pliocene/Pleistocene sands with coral inland reefs and limestone foundations reaching inland (in some places) for miles.

Illus. 95 Animal fossils are often easier to come by than plant fossils. Here though, you see what plants looked like in Jurassic days: a Coniopteris hymenophylloides (actual size).

Therefore, most of the fossils you find in Hawaii will be relics of Cenozoic sea life. And gastropods and pelecypods hold sway over these marine forms. On Oahu you can gather up the shells of mollusk species that are now extinct or are slowly dying out in this very age. The Oahu beaches also contain the fossilized remains of many species of snails, slugs, oysters and mussels which ages ago resided in the waters surrounding Hawaii but can now be found, living, only in other parts of the world.

Oahu itself yields up fossilized mollusks of a type living only in drowned river mouths. But you will have to dig through the overlying turf of volcanic deposits to collect these. And coral, of course, abounds. Maui Island's beaches offer a great many gastropod and brachiopod shells, but they are finely fragmented. So, too, are the petrified colonies of globe-shaped algae, now turned to coral. Menke, at the exact spot where the mouth of a tributary stream meets the inland river, is one of the best places on Maui to go collecting relics of ancient marine life.

Molokai is the third most fossil-rich island of Hawaii, with corals and Cenozoic snails and cockles again predominating.

For more complete information, write: Division of Hydrography, Department of Public Lands, Honolulu, Oahu, Hawaii. 96800.

Idaho

Oddly-shaped Idaho is dominated by a batholith, if one thinks in terms of physical area alone. For Idaho's share of the Rocky Mountain System was upthrust by the Laramide Revolution (which closed the Cretaceous Period) into the older Rocky Mountain Range. (The first Rocky Mountain System dates from Permian times.) So this impressive mass of intrusive (batholithic), igneous rock necessarily means a lack of fossils.

Still, a few areas in the batholithic area stand out: Lemhi County with its scattered deposits of Jurassic plants; Adams and Nez Perce Counties with their opalized wood—and Washington County whose opalized wood rivals even Ada's (south of the batholith) in beauty and is more interesting because you generally have to dig though volcanic ash to get to it.

The south and west of the "Gem State" fall outside this batholith, however, and here you will find whole areas of exquisitely opalized timber. Ada County, for instance, is noted for the beauty of its opalized wood. Lincoln County also has outstanding samples.

Marine fossils are considerably scarcer than petrified wood. Still, Bear Lake County yields up some Cambrian brachiopods. Oneida adds Cambrian trilobites to its brachiopod offerings. Power County has plenty of reefs formed by the unusual horn or "cup" corals. But Cassia County is perhaps the richest in marine fossils, with its silicified bryozoa, fragments of sea-lily stems, and even some samples of extinct spirifers (see page 83). These all date from the Pennsylvanian Period. Most marine fossil sites fall outside the batholith.

For additional information, write: Idaho Bureau of Mines, Moscow, Ida. 83843.

Illus. 96 This 10-armed squid fossil was found in northeastern Illinois. From the wealth of trilobites, sea scorpions, pelecypods and horseshoe crabs also in that area, we know that part of the state was once deep ocean. This Permian creature is a Jeletzyka douglassae.

Illinois

Fossils from every era are abundant in Illinois. In the east and north you may find very well-preserved fossils of the ancient Paleozoic era, especially crinoids (echinoderms more popularly known as "sea lilies") and trilobites of the Silurian and Ordovician eons. Farther south, in the De Kalb County area, are more modern samples from the Pleistocene epoch, including mastodon remains. Good hunting grounds are Grundy County, Hancock County (one of the richest fossil localities in America), and Monroe County; also the Chicago vicinity—in fact, all of Cook County. Ancient scorpions, corals, fern imprints, and shellfish are plentiful in all these areas.

For helpful maps and a fossil guidebook, you may write to: Illinois State Geological Survey, Natural Resources Building, Urbana, Ill. 61801.

Indiana

Ancient fossils abound in Indiana, especially the Silurian chain corals and graptolite formations that stretch west to southeast across the state: from Newton County all the way to Adams County. Stunning coral-reef formations are common in Miami, Huntington, Madison, Grant, and Wabash Counties. This region abounds, too, in dead bryozoa and stromatoporoids—so plentiful that their amassed remains also form reefs. [The Stromatopora are valuable fossils because, unlike most of their close relatives, the jellyfishes and sea anemones, the stromatoporoids secreted hard parts. These minute square-shaped hydrozoa died out in the Cretaceous Period, but not before they had left behind them such dense calcium carbonate deposits as to form many of the rocks we date as Devonian.]

Shale and reef formations from Ordovician to Pennsylvanian times run from east to southwest across the state. Brachiopods, trilobites, and corals abound in these rocks. Dubois County is known to serious fossil collectors all over the United States because its soils contain fossil representatives of every phylum in the animal kingdom—even the minute forams.

You may obtain more detailed information by writing The Department of Earth Sciences, Purdue University, Lafayette, Ind. 47907.

Iowa

The middle and recent eras are abundantly represented in Iowa fossil deposits. Vertebrate remains pop out of nearly every erosion gully, railroad gorge, and highway cut. Plymouth County still preserves deer and bison horns dating from Pleistocene times as well as the teeth and leg bones of Pleistocene elephants and horses. In addition, Devonian limestone juts out here and there throughout much of Iowa. These formations encase such older samples as ostracods, leaf shrimp (the echinocarids), and 79 different species of the long-extinct trilobites. In fact, almost every county offers some kind of trilobite, with Fayette, Cedar, Cerro Gordo, Clayton, Dubuque and Johnson being the most notable for this particular type of marine arthropod. Franklin and Des Moines Counties stand out because of their rich *variety* of fossils: Mississippian sponges, brachiopods, fishes, oysters, mussels, sea lilies, crustaceans, and the almost ever-present trilobites. Marshall County's sea lilies are world-famous because you can find them petrified in their original "nests"; and even the most delicate structures of the individual animals are perfectly preserved. If you are lucky, you can even find some that retain their original color!

Maps and literature are available at the Iowa Geological Survey, Iowa City, Ia. 52240.

Illus. 97 A graptolite exoskeleton: In some parts of America the graptolites were industrious reef-builders.

Kansas

The "Sunflower State" is rich in fossils of *all* eras. For the remains of the Paleozoic era, including trilobites and ancient insects, you may search the Verdigris and Vermilion River valleys. (Greenwood County in this area is also noted for its fossilized jellyfish.)

Even more famous than the Permian insect beds are the Cretaceous formations to be found in such counties as Cherokee, Logan, Phillips, and Norton. Here the skulls and other bones of mosasaurs (huge, extinct marine reptiles that are interesting to us because they combined a long snakelike body with a lizardlike head and two pairs of paddle-shaped limbs) plus those of extinct birds that—like our modern-day penguin—could not fly are extensive. Ness County yields up not only mosasaurs, but dinosaur remains as well. These same widely scattered counties also offer a species of sea lily, fascinating because its members floated in colonies—and were so abundant as to be preserved as "nests" in the chalk soil.

Osage County contains the largest ammonites found anywhere in the world. But in Lyons, Montgomery, and Leavenworth Counties—in fact, throughout eastern and central-eastern Kansas—pelecypod fossils prevail in number over all other forms of bygone marine life.

The more modern Cenozoic samples, including the bones of camels, elephants, mastodons, saber-toothed cats, mammoths, and dire wolves* are to be found in Kansas' far western counties: Cheyenne, Sherman and Greeley for instance, and especially Wallace. In these counties you should search all rock outcrops, gorges in rock formations, and dried-up stream beds. The most valuable find among all these Pliocene/Pleistocene mammals would be the bones of a special horse—the first species to develop just one toe. For the extreme west of Kansas, merging into the Rocky Mountain area, was once a home to these probable ancestors of our present-day horses.

Finally, Kansas is known to fossil-hunters the world over for the daintiness of its Pennsylvania-years

bryozoa. And these especially lacy-patterned little "moss animals" can be found with ease in the Pennsylvanian outcrops that spice certain areas of the state (Johnson, Russell, and Wyandotte Counties, for instance).

Helpful publications are available from The State Geological Survey of Kansas, Lindley Hall, University of Kansas, Lawrence, Kans. 66044.

**NOTE:* The dire wolf (extinct) was a carniverous member of the dog family. In size he approximated our modern-day timber wolf, but his teeth were nowhere near as sharp as those of contemporary wolves. Although Kansas and some of our Rocky Mountain states hoard his bones, you can get a true-to-life picture of what he looked like if you go to Los Angeles. For the La Brea tar pits (see page 77) trapped many of these dire wolves as they went down to drink from treacherous waters. The dire wolf is the direct descendant of a much dumber dog-type animal (smaller brain case) who perished at the end of the Eocene Epoch.

Kentucky

In Kentucky you may find extremely old Mississippian, Ordovician and Silurian fossils of sea animals, including the unusual "glass" sponges. Breckenridge, Casey, Meade, and Russell Counties have interesting protozoa, brachiopods, and sea lilies plus other samples of Paleozoic sea life. West of the Tennessee River are remains of Cretaceous, Tertiary and Pleistocene mammals. Beautiful coral formations are notable throughout the state, especially in Jefferson County.

More detailed information is obtainable from the Kentucky Geological Survey, University of Kentucky, Lexington, Ky. 40506.

Louisiana

The "Pelican State" is sparse in fossils. Those we can find had to survive the receding of the Tertiary seas. Therefore they are isolated and mainly Cenozoic in nature—with Eocene sea life predominating. Grant Parish is recognized as the most fossiliferous area of Louisiana because of its abundant (for Louisiana) mollusk beds, oysters, and fish bones—mainly Eocene. Eocene sea life is also widespread in Natchitoches Parish, with its fossilized gastropods, sea anemones, and many varieties of pelecypods. Bienville Parish has Eocene shellfish and sea urchins. Cenozoic mammals are represented by the Pleistocene horse and mastodon remains of Iberia Parish. Here, too, you may find some rare Pleistocene mylodon relics (toothless animals native only to the Western Hemisphere and related to the sloths, armadillos and anteaters). Plant fossils can be found in West Feliciana and Caldwell Parishes.

For more information, write to Louisiana State Geological Survey, Louisiana State University, Baton Rouge, La. 70803.

Maine

Fossil-hunters will find the "pickings" very slim in the "Pine Tree State." For Maine has been eroded right down to pre-Paleozoic bedrock by massive Pleistocene ice fields. However, Aroostock County with its scattered Paleozoic outcrops can be made to yield up Silurian brachiopods and even some Ordovician graptolites. Knox County, too, has some Paleozoic outcrops, and in these you will find Silurian brachiopods, annelids, some 80 species of invertebrate sea animals, and even sea-lily fragments. Unfortunately, it is almost impossible to get from Maine a fossil that is in good condition.

More details may be obtained from the State Geologist, Geological Survey, Orono, Me. 04473.

Maryland

Maryland is a very fossiliferous state, containing samples of all three eras. The Coastal-Plain area has abundant teeth belonging to Miocene sharks and whales. (Specifically, this area includes the counties on both sides of Chesapeake Bay and even the environs of Baltimore.) In "Potomac Counties," such as Charles and Prince George, dinosaur remains almost monopolize the fossil finds—perhaps because of their dramatic impact and because all suborders of the dinosaur are represented in Maryland. Crocodile and turtle remains are next in impact and abundance in these counties—with the relics of ganoid fish coming in third. (The ganoids—or Ganoidei—are a subclass of fish characterized by hard-enameled scales. Most ganoids are extinct today, but we recognize our present-day sturgeons as their survivors.) St. Mary's, another Potomac county, boasts mastodon teeth—especially those of the mammuts—and other Pleistocene vertebrate remains.

Allegany County has massive beds of the extinct Stromatopora plus a vast variety of other Devonian sea creatures—especially ostracods (24 species) and the extinct spirifers (a genus that once formed a significant part of the entire brachiopod population but whose remains are extremely hard to find; the spirifers were set off from the other bivalved sea life by having their arms supported by stiff, platelike organs; they did not make it past the Jurassic Period).

Washington County, too, is rich in ostracods. Fossilized vegetation abounds in Ann Arundel, Baltimore, Kent, and St. Mary's Counties.

Maryland provides especially fine information on her fossil wealth. Write to Department of Geology, Mines, and Water Resources, Johns Hopkins University, Baltimore, Md. 21218.

Massachusetts

You will not find a large number of fossils in Massachusetts. In fact, few areas outside the Connecticut Valley are worth mentioning. Cambrian fossils prevail in Essex County with its brachiopods, annelids, and "microfossil" mollusks. Most important though, Essex County offers samples of extinct seaweed (the fucoids) and several varieties of *Hyolithes* [a genus of gastropods that went extinct in the Cambrian Period and are highly unusual in that they took to vigorous swimming (most gastropods are notoriously "lazy")]. In the rest of the Connecticut Valley Triassic samples prevail. Hampden, Hampshire, and Franklin Counties all preserve fish and vegetation from that period. Franklin County is the best place to go though—especially around Turner's Falls and Sunderland. For here you will find what are probably the only *well*-preserved fossils in Massachusetts.

Still, the "Bay State" makes up in drama what it lacks in number and good condition of its fossils. For Massachusetts' share of the Connecticut Valley also teams with dinosaur tracks. Here—in the Triassic shales around Belchertown, Greenfield, Turner's Falls and Springfield—you can photograph the perfectly preserved footprints of five different species of dinosaurs. Other huge footprints also pervade the Valley—and these have been identified as belonging to three species of extinct monster-sized reptiles.

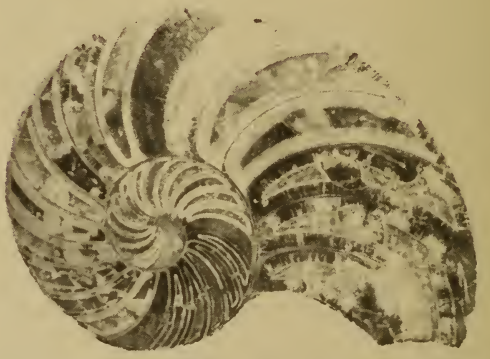
For more information write: The Curator, Ecological Museum, Harvard University, Cambridge, Mass. 02100.

Michigan

Michigan's fossil deposits are respectably abundant, with all road cuts and the limestone deposits of the various islands proving especially rewarding. The Eastern Peninsula, long ago sliced off from the rest of the state by a Pleistocene ice lake, is understandably poorer in fossils than the mainland. But you can still find Silurian fishbones in Chippewa County and—if you look hard enough—algae formations of gemlike quality in Marquette County. (Technically called "stromatolites," these "algae-rocks" ossified by silicon replacement are highly sought after by jewelers who cut and polish these "plant gems" and then sell them to discriminating customers.) Drummond Island in Lake Huron will yield up a Silurian brachiopod known informally as "petrified deer's foot" plus the highly interesting "pipe organ" corals.

On the mainland, Alpena County preserves Devonian cuttlefish, bryozoa, and sea lilies. Delta County contains cup-coral formations we can identify as Ordovician, plus massive graptolite deposits. Iosco County offers clams and oysters plus nautiluses and other cephalopods—all Mississippian in Age. Monroe County has the famous Monroe Fossil Beds with their stromatoporoids and rare spirifers and lentil-shaped trilobites. Various corals are extensive throughout the mainland counties, and obviously, sea-life predominates among Michigan's fossil population.

For additional information, write: Geological Survey Division, Department of Conservation, Lansing, Mich. 48900; or Geology Department Museum, Michigan State University, East Lansing, Mich. 48900; or Kingman Museum of Natural History, Battle Creek, Mich. 49000.



Illus. 98 Nautiluses abound in Michigan and Minnesota.

Minnesota

Although much of Minnesota is covered with sand-clay-gravel "drift" occasioned by the Pleistocene glaciers, the "North Star State" nevertheless excels in trilobites, graptolites, and brachiopods that are both exceptionally well preserved and among the earliest samples we can find anywhere in the United States. Extremely primitive (and therefore early) species of gastropods are another of Minnesota's fossil specialties. Goodhue County has the best of these trilobites (Cambrian in age) along with abundant bryozoa, corals, mollusks, nautiluses, snails, limpets, and abalones—all from that period. The creek beds of Chisago County hide plenty of Cambrian sponges. Many counties abound in Ordovician samples: Hennepin with its sponges, corals and trilobites; La Sueur with its clams, mussels, and oysters; Olmsted with its corals and "microfossil" snails. Ramsey County takes a prominent place, too, in the Ordovician parade, by virtue of its fossilized bryozoa and trilobites—and, most im-

portant, its fossil representatives of an extinct genus of Nautiloidea: the *Endoceras* nautiluses that in their heyday often produced 12-foot-long shells. (We cannot guarantee, of course, that *you* will find *Endoceras* specimens that large; many have been picked over by the "experts.")

For Silurian fossils, go to Houston County with its brachiopods and cephalopods or, better still, to Fillmore County, which abounds in bryozoa, trilobites, cuttlefish, "sunflower" corals, nautiluses and other mollusks.

The Mesozoic Era is best represented in Minnesota by Itasca County. Here is the best place in the state to find fossilized insects and crabs that lived during Cretaceous times. In certain parts of Itasca County you can find Cretaceous sharks' teeth and even ichthyosaur and plesiosaur bones (see pages 52 and 53). Many cones and needles of coniferous trees managed to be preserved as fossils, too—along with the "micro-insects" that infested them.

Pleistocene mastodon bones can be picked up near Minnesota City (Winona County), but most of Winona's fossil offerings are Ordovician trilobites, brachiopods, and cephalopods.

Maps and more details will be provided by The Minnesota Geological Survey, University of Minnesota, Minneapolis, Minn. 55455.

Mississippi

Although Mississippi gives its name to almost 40 million years worth of Paleozoic strata, the "Magnolia State" is just about monopolized by Cretaceous soils. Nevertheless, Cenozoic fossils can be found in the counties comprising the great, flat Yazoo Delta: Warren with its bones, skulls and teeth of Pleistocene bears, saber-toothed cats, elephants, horses, tapirs, and —most interesting of all—giant sloths; Smith where Oligocene oyster shells measure up to a foot in diameter; Clarke and Hinds, with their Eocene sea urchins, crabs, sharks' teeth, spindle-shaped snail shells; and Wayne where you can find hundreds of borings of special Oligocene worms that we know had the same wood-gnawing appetites as our modern-day termites.

Most fascinating of all Mississippi's Cenozoic treasures, though, are its abundant Zeuglodon bones. These ragged-toothed, very slender Eocene whales went extinct at the end of their epoch of glory, but it is this particular genus of archaic mammal which has made Mississippi well known to fossil-hunters all over the world. The "belt" where you can find zeuglodont bones stretches from Yazoo County and the northernmost part of Hinds straight east to the Alabama border. (So if you live in Yazoo, Hinds, Scott, Madison, Smith, or Clarke Counties, you are in luck!)

The Paleozoic Era is amply represented by Tishomingo County's Devonian cup corals, bryozoa, trilobites, fish plates, crabs, and spirifers—all abundant. Then, too, there are the plentiful sea-lily stems, gastropods, and blastoids [a class of echinoderms shaped like lovely flower buds which went out at the end of the Permian Period. Some people categorize them as a specific kind of sea lily (crinoid). Others give them equal importance with the sea lily in the subphylum Pelmatazoa (*stalked* or *attached* echinoderms as opposed to the free-moving starfish, sea urchin, and sand dollar)].

Illus. 99. This Jurassic shale holds oysters and a piece of fossilized driftwood from that period.

Tishomingo also offers Mississippian fossils—these are found in part of the famous limestone beds that stamped the Magnolia State's Indian name on 40 million years of earth time. Tishomingo's Mississippian contributions are mollusks, sea lilies, trilobites and corals, and numerous shark teeth. The Mississippian-Period limestones stretch into nearby Alcorn and Tippah Counties, but these two counties are more famous for their Mesozoic samples. Tippah in fact contains the world-famous Ripley Formation (sediments deposited during a certain specific interval of Cretaceous time). Here in the Ripley strata—and especially its "Owl Creek Beds"—you will find a vast variety of fossilized sea urchins, sharks' teeth, and extinct oyster-types. Most important among these genera are the *Exogyra*: the first of the pelecypods to bear a true resemblance to our present-day oysters. (They did not come into being until Jurassic times and completely petered out by the end of the Cretaceous Period.) Other places to go for these valuable "pioneer" oysters are Alcorn, Chickasaw, Itawamba, Kemper, and Lee Counties (Lee having the greatest number of different species).

Fossil vegetation also prevails throughout the state, with many areas having whole stretches of petrified timber (the forest 18 miles northwest of Jackson, for instance). Moreover, Clay County has Mesozoic plants and Marshall County is outstanding for its excellent impressions of Cretaceous leaves.

Obviously then, Mississippi with its important Zeuglodons, pioneer oysters, and fossil trees is, like Alabama (see page 76), one of the most rewarding places in America to go fossil-collecting.

For additional information, write: The State Geologist, Mississippi Geological Survey, University of Mississippi, Oxford, Miss. 38655.

Missouri

Paleozoic fossils prevail in Missouri, with almost every period of that era being represented. However, since the "Show-Me State" lies in the great Mississippi Basin, its richest hoard is, naturally, organic remains from the Mississippian Period. Barry County, for instance, abounds in corals, blastoids, primitive echinoids (sea urchins, sand dollars, and other free-moving echinoderms), various fishes, and highly developed sea lilies. Around Seligman in this county, you will also find the molds of all these creatures. Boone County also has its share of all these Mississippian life forms—plus bryozoa, worms, snails, forams, spirifers, sponges, ostracods, 71 different species of brachiopods, and the highly interesting conodonts. These extremely tiny tooth-shaped fossils are generally believed to be ostracoderm teeth. (Ostracoderms are the earliest of recorded fishes and probably the first life forms to develop a spinal column. They were jawless and are represented today by only our lampreys and hagfishes.) Most important though, Boone County is famous as the best place in the *entire* Mississippi Valley to go for sea lilies (260 different fossil species nest in its soil). Greene County abounds in brachiopods, pelecypods and cephalopods (17 different species) from the Mississippian eons. Other counties rich in Mississippian life are St. Genevieve (the area around Establishment Creek); Pettis (look around Sedalia); Jasper with its sea lilies featuring unusually large stems; and Perry with its clams, mussels, and snails.

Madison County is the place to go for Cambrian fossils. These include various brachiopods, very old trilobites and snails, and some corals. Look for them in the shale beds. Shannon County's Cambrian offerings are mainly snails, abalones, whelks and trilobites. However, near Grassy Creek in this county you will find *Euomphalopsis* that we can identify as Ordovician creatures. (These unusual snails with their depressed conical shells were extinct by the end of the Mesozoic Era.) Then there is Jefferson County with its abundant graptolites, trilobites, conodonts, bryozoa, ostracods, crabs, sea lilies, nautiluses, and petrified worms and plants—all dating from the Ordovician years.

Silurian corals abound in Pike County. So do sea lilies, snails, whelks, trilobites, clams, and brachiopods of that Period.

Devonian animal life is well represented in Callaway County with its many species of brachiopods, corals, and fish teeth. Cooper County contains many samples of an extremely large snail that lived in Devonian times (the *Turbinopsis providencis*—rare in most parts of America). Corals are notably abundant here. Marion, Ralls, Pike, and St. Louis Counties also offer Devonian cuttlefish, worms, sea lilies, conodonts, corals and fossilized plants, although along the county line dividing Marion from Ralls, Mississippian spirifers are the specialty.

Well-preserved Pennsylvanian mussles, clams, and oyster-types are to be found in Cass County. But Platte, Buchanan, Andrew, Clay, Clinton, and De Kalb Counties are also good hunting grounds, with abundant brachiopods, 32 different species of gastropods, and 30 species of pelecypods all yours for the looking.

All in all, Missouri proves the paleontologist's insistence that Mississippian formations are characterized by an abundance and variety of sea lilies. For additional information, write The Division of Geological Survey and Water Resources, Buehler Building, Rolla, Mo. 65401.

Montana

Extensive mining in this mineral-rich state has

Illus. 100 This Trachodon or "duck-billed" dinosaur was a close relative of Montana–Wyoming's Triceratops, although the Trachodon used just 2 feet to walk on. Both dinosaurs were herb-eaters.

destroyed many fossil beds there. Moreover, the "Big Sky State" was also given a spiny topography by the Laramide Revolution, so that in the batholith areas, only Mesozoic and Cenozoic relics survived. Nevertheless, Sheep Creek Canyon and its environs (Beaverhead County) managed to preserve a fair amount of Mississippian bryozoa, corals, and brachiopods. The rest of the county, however, is almost monopolized by the Mesozoic samples that are so characteristic of Montana's fossil population: Blacktail Creek, for example, with its Triassic ammonites, mussels and oysters; the banks of Little Water Creek with their Jurassic *Gryphaea* (an oyster-type closely related to the pioneer *Exogyra*—see page 86) and special star-shaped sea lilies. Big Horn County is another area that managed to preserve some of the Paleozoic life it once supported. Here Pennsylvanian ammonites and silicified corals are the main treasures.

Jefferson County still retains bryozoa, sea lilies, cuttlefish, and ostracods from Devonian times. Here, too, you can see actual trails delved into the earth by long-gone Devonian worms. Judith Basin County's most interesting Devonian contributions are sharks' teeth.

Despite sparse pockets of Paleozoic fossils, Montana is best known among "rockhounds" for dramatic dinosaur bones. Dawson County alone offers relics of four different dinosaur species, among them the famous carniverous *Tyrannosaurus* and the huge *Triceratops* whose skull was 8 feet long. Crocodile and turtle remains are also easy to find in Dawson County. Madison County is the second best place to go for dinosaur bones. Here you will also find the relics of an extinct animal somewhat like our present-day rhinoceros.

Meagher County is one of the few places in America where you can find pre-Paleozoic brachiopods. And don't forget Glacier National Park with its pre-Cambrian worm burrows and beautiful algae formations (stromatolites) of the same mist-shrouded eras.

For more information about Montana's fossil wealth, write: the Montana State Bureau of Mines and Geology, Montana School of Mines, Butte, Mont. 59701.

Nebraska

The oldest fossils in Nebraska are Pennsylvanian relics in the southeast counties: Nemaha with its bryozoa and pelecypods for instance, Otoe with more bryozoa. Northwestern counties such as Sioux and Scotts Bluff have been affected by debris left over from the Laramide Revolution. Here you will find mammal bones, Pliocene to Pleistocene in age: the bones, teeth, and tusks of an elephant that was usually no smaller than 8 feet; relics of the 9-foot-tall "shovel-tusker" elephant; and bones of yet another extinct elephant, the "spoon-bill." Moreover, Scotts Bluff County is noted for its immense hoard of the bones of an extinct bison—plus the bones of many other mammals that did not live past the Pleistocene Epoch. Sioux County is so rich that it defies description: Oligocene lions, dogs, tapirs, camels, and rhinoceroses are just a few samples. In another part of this county—the Agate Bone Beds 23 miles southeast of Harrison to be specific—are representatives of the Miocene

world: gazelle-like camels, giant pigs, and the so-called Devil's Corkscrews (you can see these 6- to 8-feet-deep burrows not only in Sioux County, but in many other western counties of Nebraska as well. They are believed to be the work of Miocene beavers).

Gosper County is so full of Pleistocene-mammal bones that you need not make any effort to look for them. The Little Badlands area of Dawes County will yield up alligator remains plus those of rhinoceroses and saber-toothed cats.

Lincoln County can boast of abundant Pleistocene-mammal relics—especially gophers and their rodent kindred (much larger than our present-day specimens). Here, too, in the Sand Hills region near Platte River, you can find arrowheads and many household articles (sometimes fragmented) of the Indians who enjoyed Nebraska during prehistoric eons.

Aside from these dramatic areas of mammal bones and the Pennsylvanian pocket in the southeast, most of Nebraska offers Cretaceous fossils—with bryozoa predominating. Cass County is one of the richest in the Cretaceous "zone," with its corals, sea lilies, mollusks, trilobites, sponges, brachiopods and—of course—bryozoa.

Opalized wood is available in Cherry County and in some parts of Duell County.

Maps and other publications are available from The State Geologist, Conservation and Survey Division, University of Nebraska, Lincoln 8, Nebr. 68503.

Nevada

In Nevada, most fossils are Paleozoic. Nevertheless, Mesozoic rocks assert themselves here and there, and eastern Nevada has caves that did such a good job of preserving Pleistocene mammals that even these warm-blooded animals' hides and hairs are intact. Even in the Paleozoic counties some vertebrate remains (undated) have been found, along with whole areas of fossilized land plants and petrified forests.

Elks County's shale beds are rich in Cambrian graptolites; but for Cambrian trilobites, go to Eureka, White Pine, and Lincoln Counties (Lincoln having the greatest variety of species).

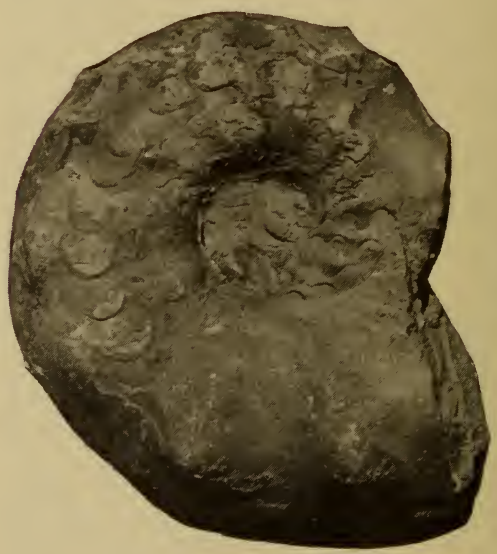
Eureka also represents the Devonian Period quite respectably (stromatoporoids, "honeycomb" corals, trilobites), while White Pine does a good job with Silurian shellfish and yields up spirifers from both the Mississippian and Pennsylvanian Periods.

For Mesozoic life, go back to Eureka County with its Cretaceous corals (cup), brachiopods, and spiral-shelled snails. (Eureka County is, in fact, so fossil-rich that the U.S. Geological Survey devoted an entire volume to its paleontological offerings.)

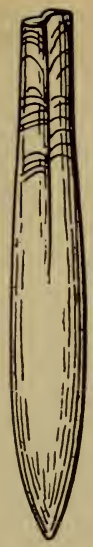
Humboldt County, especially around Rattlesnake Point, is rich in Triassic nautiluses and the ammonites that—by now highly developed and bearing a variety of exquisite "sculptured" patterns—were enjoying one of their last periods of marine supremacy. Mineral County is another Triassic delight, with its oysters, mussels, corals, and ammonites. Miller Mountain in this county is an Ordovician stronghold with its samples that range from graptolites to petrified wood.

Nye County is Nevada's most spectacular claim to paleontological fame because it confines Nevada State Ichthyosaur Park. Here you will see whole skeletons of this, the dinosaur's most publicized "cousin" (see page 53) on display. Other Jurassic curiosities on display there are plesiosaur fragments, specialized ammonites (even more intricately patterned than their elaborate Triassic predecessors), and belemnites (cephalopod creatures, looking much like our modern-day squid, which abundantly ornament Jurassic rocks; they had internal skeletons shaped like cigars and for all their celebrity, went extinct at the end of the Cretaceous Period—see also page 37). Naturally, you cannot do any collecting in the Ichthyosaur State Park, but right outside its environs are Jurassic nautiluses and ammonites to be picked up just by stooping down.

For more details, write: The Nevada Bureau of Mines, University of Nevada, Reno, Nev. 89507.



Illus. 101 *A Ceratites nodosus—Triassic ammonoid. Compare its suture pattern with Jurassic samples. Nevada excels in ammonites.*



Illus. 102 The internal parts of belemnites are what you will find as fossils. Note their shape.

New Hampshire

Between its igneous bedrock and the beating it took during the Pleistocene Ice Ages, the Granite State has little left to offer fossil fans. Still, Grafton County can be quite rewarding, with its Silurian trilobites, sea lilies and chain corals. Its Devonian survivors are mainly snails, limpets, and whelks; and in the Woodsville area of this county, you will find those extremely rare brachiopods that can make a rockhound's whole day worth-while—the spirifers (see page 83).

In Coos County, northeast of Dalton Mountain you will also come upon some Devonian gastropods and brachiopods that New Hampshire managed to preserve despite all its geological trials. Throughout these two counties, the best places to investigate are limestone and slate deposits.

For more information, write: The New Hampshire State Planning and Development Commission, Conant Hall, University of New Hampshire, Durham, N.H. 03824.

New Jersey

Gems are the chief fossil hoard of the "Garden State." (For instance, the carnelian bed in back of the "Charlie Brown" restaurant in Watchung, New Jersey, is famous throughout most of the Northeast States.) Organically, Cretaceous and Cenozoic fossils are the main attraction. For New Jersey, like Delaware, is made up mostly of Atlantic-Coastal-Plain sediments. Monmouth County is especially rich with its Cretaceous brachiopods, mollusks, snails and whelks; crabs, cuttlefish, and oysters (including the *Gryphaea*)—all appearing in many species. You cannot do any collecting on the historic Monmouth Battleground, but if you look closely, you will find that it is rich in nautiluses, ammonites, belemnites—and here and there are a few *Exogyra* left over from the Triassic years.

Mercer County yields up Triassic crayfishes and crabs plus *Diplurus* fish, species of the very important and rare coelacanth fossils (see page 30).

Still, New Jersey maintains some Paleozoic pockets: Passaic County, for example, where you can find Silurian brachiopods and honeycomb corals; and Sussex County with its Cambrian trilobites, Silurian clams and ostracods, Devonian brachiopods, and Ordovician trilobites and shellfish.

For marine life from the Pleistocene Epoch, check the Mullica Hill Fossil Beds in Gloucester County.

For well-illustrated guides to these fossils, write: the Bureau of Geology and Topology, 520 East State Street, Trenton, N.J. 08609.

New Mexico

The "Land of Enchantment" is a very rocky state, punctuated by deserts. This may make fossil collecting difficult, but New Mexico's fossil deposits are so rich that digging is well worth the effort. In the Ladron Mountain region, Mississippian formations will provide you with cup corals, sharks' teeth, bryozoa, snails and brachiopods and—of course—the characteristic sea lilies and blastoids.

San Juan County has very interesting Late Cretaceous to Pliocene fossils, including ganoid fishes, insects, primitive opossums, armadillos, mouselike rodents, primates that were the ancient ancestors of our monkeys, Eocene carnivores (see page 82) and plant-eating hoofed animals.

The earliest specimens are the Permian trilobites and sponges to be found in the southwestern counties —Grant and Hidalgo, for instance. (The world-famous Carlsbad Caverns in southeastern Eddy County are also Permian in composition.) Among the most fascinating sights are the "Bat Caves" of Sierra County formed out of Ordovician strata and another bat-inhabited cave in the Caballo Mountains of that county—this one containing Devonian bryozoa, nautiluses, and gemlike algae.

Write to New Mexico Bureau of Mines and Mineral Resources, Campus State, Socorro, N.M. 87801.

Illus. 103 This stone arrowhead was found near Folsom, New Mexico, along with the bones of mastodons and of extinct camels. So we know that the first inhabitants of North America reached our continent early enough to hunt mammals typical of the Pleistocene Epoch.

New York

The "Empire State" is thought by many to be the most fossiliferous in the country. Moreover, its specimens are particularly well preserved. Excluding congested New York City, Pleistocene mastodon bones are easy to find throughout the state—notably in Orange, Orleans, Wyoming, Monroe, Genesee, Livingston and Chautauqua Counties. (Even in Manhattan which has been rearranged so much by man, you can see vestiges of the Pleistocene Epoch in Central Park: the distinct scratchings left by Pleistocene glaciers on the huge granite boulders.)

Albany County is an especially fine place to look. Your rewards will be high-quality brachiopods ranging from Cambrian to Devonian in age. Moreover, Devonian mollusks, graptolites and even the usually rare spirifers abound. In fact, these extinct brachiopods, so hard to find in most of America, are available in Broome, Cattaraugus, Cortland, Greene, Orange, Chenango, Schuyler, Chemung, Schoharie, Steuben, and Oswego Counties—with Devonian-Period spirifers predominating. Schoharie is also rich in fossilized mollusks and salt-water crabs.

Erie County offers Devonian trilobites, blastoids, and graptolites, while giant sea scorpions of Silurian age are the specialty of Niagara County. Monroe County is great for Silurian nautiluses and cuttlefish. Onondaga County—including the outskirts of Syracuse—is rich in Devonian gastropods. Chenango County, besides its spirifer wealth, offers Devonian sea lilies and worm trails and ancient crustacean tracks. For these—and for fossilized seaweed—look in the sandstone deposits.

Fossil-teeming New York State does a fantastic job of preserving its bygone plant life, too. In Long Island's Nassau County you will find abundant leaf prints dating from the Cretaceous Period (10 different species of extinct plants have so far been identified). Saratoga County carefully cherishes its Cambrian algae, so hard to come by.

For more details, you may write to the State Geologist, New York State Science Service, Albany, N.Y. 12201.

North Carolina

Mesozoic and Cenozoic fossils are abundant in North Carolina. Cretaceous deposits are found in Pitt, Lenoir, Greene, Pender, Duplin, New Honomer, Bladen, Columbus, and Brunswick Counties; the Wilmington area contains fine mollusks, bryozoa and starfishes from the same time. Plant and vertebrate fossils from the Jurassic period are in the Raleigh–Durham area, and Pleistocene deposits along the coast and slightly inland. Columbus County has Pliocene oysters, clams, snails and the bones of our present-day horse's extinct ancestor. Tertiary shells and sharks' teeth, and Pleistocene hooves and mammal bones are in Craven County. Look for Miocene crustaceans, gastropods, scaphopods (specialized mollusks with tubular shells and no real differentiated respiratory system) and pelecypods in Halifax County.

Write to: North Carolina Division of Mineral Resources, Raleigh, N.C. 27600.

North Dakota

This state has remains ranging from Devonian fossils in western counties to Mississippian, Jurassic, Cretaceous and some Pleistocene in other areas. Fossil-hunting is more difficult in the western areas. In Billings County you may find Cretaceous turtles, fishes, shells, and dinosaurs; and very interesting Oligocene fish, rhinoceroses, three-toed horses, and crocodiles. Emmons County has Cretaceous reptilian bone fragments, and Morton County may reveal interesting crocodile teeth, bone fragments and gastropods from the same period.

Information and maps are available from The North Dakota Geological Survey, University of North Dakota, Grand Forks, N.D. 58200.

Ohio

Ohio is an extremely fossiliferous state. In the southwest are Ordovician fossils; also available are Silurian and Devonian remains, the latter in the northwest and including the famous predator fish that were 24 to 30 feet long. You may find Missis-

sippian rocks in Defiance, Williams, and Fulton Counties and Pennsylvanian rocks in the north. Most important of all are the Pleistocene Ice Age mammalian remains of teeth, bones, and skulls of such animals as mammoths, giant beavers, sloths, deer, mastodons, bison, moose, and musk-oxen.

Look for Ordovician bryozoa, brachiopods and corals in Green County, including Yellow Springs. Look for Silurian corals, brachiopods, cephalopods and gastropods in Miami County.

For a fossil guidebook, write to: Ohio Geological Survey Bulletin No. 54, Ohio Geological Survey, Department of Nat. Resources, 106 Orton Hall, The Ohio State University, Columbus, Ohio 43210.

Oklahoma

Fossil formations in this state are of the ancient and middle periods. The Arbuckle Mountains are fossiliferous; look for petrified wood in Beckham and Tillman Counties. Pleistocene remains of mammalian bones and teeth are in the Cimarron and North Canadian River areas. Look for abundant Cretaceous formations in Hughes County, including trilobites, ammonites, nautiloids, gastropods, echinoids, bryozoa, brachiopods, and pelecypods. Okfuskee County is rich in Lower Mississippian sea lilies, bryozoa, brachiopods, and gastropods.

For more details, write: Oklahoma Geological Survey, University of Oklahoma, Norman, Okla. 73069.

Oregon

There are rich Cenozoic fossil deposits in this state, including Oligocene formations in the John Day River Valley. Somewhat less abundant are Triassic rocks. In Columbia and Washington Counties are Oligocene fossil crabs, parts of sea lilies, sea urchins, crabs, pelecypods, gastropods; and Eocene pelecypods, sharks' teeth and other marine fossils. Search in Crook County for lovely silicified wood of different colors, as well as ancient Mesozoic marine invertebrates and foraminifers. In Curry County are Cretaceous clams and ammonoids. You may find Eocene deposits in Marion and Polk Counties, including a large form of nautilus, sharks' teeth, sea urchins, and foraminifers.

More details are available at the Oregon State Department of Geology and Mineral Industries, 1069 State Office Building, Portland, Ore. 97201.

Pennsylvania

This state is not extremely fossiliferous but does have some very good formations, from the Cambrian through the Pleistocene times. There are good Cambrian deposits in Lancaster and Bucks Counties, and Mississippian fossils in the northwestern part of the state, including the "glass" sponges. Susquehanna County has interesting Devonian fishes; Tioga County reveals abundant Devonian fish and shell remains, including armored fish. In Fayette County are Devonian wormtrails, bryozoa, sea-lily columns, brachiopods, pelecypods and fragments of ancient plants. Indian arrowheads abound in the north-central counties. In fact, The Pennsylvania State University runs a special summer course in excavating arrowheads and other artifacts from the abandoned campsites of prehistoric Indians.

Write to the Bureau of Topographic and Geological Survey, Department of Internal Affairs, 604 So. Office Building, Harrisburg, Pa. 17120.

Rhode Island

This state is extremely unfossiliferous. The few remaining fossils are Pleistocene to Holocene (today's epoch), but specimens are very difficult to find. Don't despair though: you can always take a bus trip to the dinosaur-stamped Connecticut Valley, and it's just

Illus. 104 These brachiopods are filled with Paleozoic plant fossils and thus greatly interest geologists working for coal companies.

a short boat ride to Long Island's fossil-teeming counties.

If you wish any other information, you may write to the Rhode Island Development Council, State House, Providence, R.I. 02903.

South Carolina

Most fossil localities in this state are Cenozoic. Along the coast and beside the Intracoastal Canal are rich Pliocene and Pleistocene deposits. You may find Eocene fossils in Dorchester County, including sharks' teeth, mollusks, corals and bryozoa. Florence County has Cretaceous mollusks, coral, bryozoa, pelecypods and gastropods. There are abundant species of Miocene mollusks in Sumter County.

For more details you may write to The South Carolina Geological Survey, University of South Carolina, Columbia, S.C. 29208.

Illus. 105 *This is an ostracoderm. (See also the sketch on the title page.) The first fish were not only armor-plated, but also jawless!*

South Dakota

Cretaceous deposits are predominant in this state. Excellent cephalopod fauna are available. The Black Hills are fossiliferous, including Ordovician ostracoderms or armored fish. Look for Cretaceous ammonoids that have lovely pearly shells, in Custer County, as well as coral, large cephalopods, cycads and petrified palm. Jackson and Pennington Counties are rich in Oligocene formations: petrified trees, skull and bone remains of animals such as a piglike ruminant, a 14-foot rhinoceros, tapirs, three-toed horses, saber-toothed cats, ancient pigs and camels, and small dogs.

More information may be obtained from the South Dakota State Geological Survey, Union Building, University of South Dakota, Vermillion, S.D. 57069.

Tennessee

Tennessee has fine Paleozoic, particularly Ordovician, fossils. The latter include an unusual glass sponge. There are also good Silurian formations, among them a preserved glass-sponge fossil of a different type. Coffee County preserves Mississippian bryozoa and Ordovician pelecypods and gastropods. Davidson County is quite fossiliferous, including Ordovician bryozoa and Mississippian sea lilies. You may find Ordovician gastropods, pelecypods and mollusks in Maury County. Prolific Williamson County has many Ordovician bryozoa, trilobites, and parts of gastropods and cephalopods.

You may write to: Department of Conservation, Division of Geology, G–5 State Office Building, Nashville, Tenn. 37219.

Texas

Texas rocks range from Cambrian to Pleistocene. Northern and central Texas are mainly Cretaceous. Among these the well-known Comanche series include snails, oysters, clams, ammonoids, sea urchins, foraminifers and vertebrate remains. Baylor County contains Permian fossil formations including amphibian skulls, reptiles, and plant remains such as conifers and ferns. In Cretaceous Brewster County you may find particularly ammonoids, as well as foraminifers, bryozoa, brachiopods, corals, gastropods, and pelecypods. Look for Pennsylvanian sea lilies in Brown County. Pennsylvanian sea lilies are also abundant in McCulloch and Palo Pinto Counties.

More information is available at the Bureau of Economic Geology, The University of Texas, 18th and Red River Streets, Box B, Austin, Tex. 78712.

Utah

This is a very fossiliferous state, containing samples from Cambrian to Pleistocene times. Mississippian and Pennsylvanian sea lilies are abundant in rock formations southwest of Salt Lake City. You may find Cretaceous fish, ostracods, pelecypods, dinosaur bones, and silicified wood in Emery County. Similar fossils are in Grand County, in addition to fascinating dinosaur knuckles and bone fragments that have become gemlike in appearance. Look in Millard County for Pleistocene camel remains, and Ordovician trilobites, corals, brachiopods and cephalopods. Salt Lake County contains Cambrian trilobites, corals, and brachiopods.

If you are lucky enough to live in Utah or nearby, be sure to visit Dinosaur National Monument in the fossil-teaming Uinta Mountains. This unique state park stretches all the way into northwestern Colorado.

Write to: Utah Geological & Mineralogical Survey, 200 Mines Building, University of Utah, Salt Lake City, Ut. 84112. (Note: In a few areas of Utah, you will need permission from the state authorities to take home fossils.)

Vermont

This state contains excellent Cambrian fossils, as well as Silurian fauna. You may search in the Taconic Mountains, and in northwestern Vermont, where there are trilobite and invertebrate remains. In Chittenden County is a famous Pleistocene skeleton of a whale, excavated in 1849. Abundant Silurian trilobites are in Franklin County, while in addition you may find sea lilies and coral from this period in Grand Isle County. Look for a famous Pleistocene fossil discovery in Rutland County: the teeth, bones and tusk of an elephant excavated also in 1848.

More details and maps are available from the Vermont Geological Survey, East Hall, University of Vermont, Burlington, Vt. 05401.

Virginia

Virginia fossils range from Cambrian in the southwest to Pleistocene along the coast. Ordovician and Cambrian fossils are in Bland, Rockbridge, and Smyth Counties. Silurian sea-lily stems are in Alleghany County, Ordovician cephalopods in Frederick County. In Roanoke County are a variety of Ordovician remains, including trilobites, graptolites, sea-lily stems, bryozoa and plant fossils. Scott County is well endowed with Ordovician brachiopods, sponges, cystids, corals, algae, sea lilies, gastropods, cephalopods, trilobites, and bryozoa.

Write to: Department of Conservation, Geological Survey Division, University Station, Charlottesville, Va. 22903.

Washington

Most fossils in this state are Cenozoic. In western Washington you may find numerous species of the Eocene Epoch, including gastropods, pelecypods, scaphopods and cephalopods. In Clallam County are Oligocene pelecypods, pectens, and Pleistocene mammoth teeth. If you search in Grays Harbor County you may find Miocene pelecypods and gastropods, as well as clams and oysters that have become gemlike in appearance. Similar fauna are in King County, and Eocene mollusks in Lewis County. Look for rich Oligocene deposits in Pacific County.

For more details and maps, write to: Division of Mines and Geology, 404 Transportation Building, Olympia, Wash. 98501.

West Virginia

This state has numerous Devonian fossil deposits. At the many mining sites in this state you may find such fossils as ancient amphibian bones and well-preserved plant remains. In Berkeley County as well as in Grant County, are Devonian bryozoa and corals. Hampshire County contains sea-lily fragments and bryozoa from the same period. Limestone Devonian deposits of coral are in Mineral County, while Pocahontas County has many ostracods. Look in Wyoming County for pelecypods.

Write to: West Virginia Geological and Economic Survey, Box 879, Morgantown, W.V. 26505.

Wisconsin

In this state you may find Cambrian rocks in the west-central region, including trilobite fossils; Ordovician formations; and Silurian exposures in the eastern part of the state. The latter also contain many well-preserved trilobite remains. La Crosse and Trempealeau Counties contain Silurian trilobites, brachiopods, and fucoids (see page 84). In Milwaukee County are bryozoa, mollusks and brachiopods. Look for large Silurian corals in Pierce County. Finally, Kewaunee County contains numerous gastropods, cephalopods and corals.

Write to: Wisconsin Geological and Natural History Survey, University of Wisconsin, 115 Science Hall, Madison, Wisc. 53706.

Wyoming

Cambrian trilobites, Ordovician ostracoderms and Permian fossils are located in this state, but are more difficult to find than the Jurassic and Cretaceous samples. The latter include dinosaurian remains; you may also find soft-shelled turtles from the Cenozoic Period, and very well-known, well-preserved fish fossils near the town of Fossil. Big Horn County contains excellent dinosaur bone fragments, bryozoa, sea lilies, ammonites, cephalopods and gastropods. In Carbon County is a complete Pleistocene mammoth skeleton, along with primitive Indian items that suggest the mammoth may have been killed by the Indians.

More details are at the Geological Survey of Wyoming, University of Wyoming, Geology Hall, Laramie, Wyo. 82070.

You will find additional information in J. E. Ransom's *Fossils in America*, 1964 (Harper & Row, Publishers, New York).

INDEX

Acrocoelithes (belemnite), 37
Age of Fishes, *see* Devonian Period
Agnostus pisiformis, 20
Alethopteris (fern), 46
amber, 16, 47
ammonites, 25, 35, 59, 69; *see also* ammonoids and cephalopods
ammonoids, 22, 34, 35–37, 72, 88; *see also* ammonites and cephalopods
annelids, 5, 16
anticline, 5, 8, 44
Archaeopteryx lithographica (bird), 54
Arisphinctes maximus (ammonoid), 37, 72
arthropods, 5, 19
belemnites, 22, 35, 37, 89
binominal system of classification, 28, 29
brachiopods, 5, 18, 23, 31, 32, 91
Brontosaurus, 22, 49, 50
bryozoa, 5, 19, 41
Calymene blumenbachi (trilobite), 19
Cambrian Period, 17, 18
Cardinia, 69
cast, 5, 15, 16, 59; *see also* mold
Cenozoic Era, 12, 13, 26–28
Cephalaspis (ostracoderm), 92
cephalopods, 5, 18, 34–37; *see also* ammonites, ammonoids, and mollusks
Ceratites nodosus (ammonoid), 88
Ceratosaurus, 50
chalk, 5, 22, 60
Chama squamosa (oyster), 28
chordates, 5, 30
clams, *see* pelecypods
Clavilithes macrospira, 79
Cleaning and polishing fossils, 65, 66, 67
coal, 19, 45, 47, 91; *see also* fossil plants
coelacanth, 30
Coelenterata, 6, 40, 41
Coelophysis, 50
Coniopteris hymenophylloides (plant), 80
corals, 6, 14, 18, 40, 41
Cretaceous Period, 22; *see also* dinosaurs and reptiles
Cro-Magnon Man, 58
crustaceans, 6
Dawn Horse, the, *see Eohippus*
Devonian Period, 18
Dilophosaurus, 50
dinosaurs, 22, 48–51, 87; *see also* reptiles
dinosaur tracks, 15, 16, 50
dip, 5, 6
Diplodocus, 50
double-beam-boned dinosaur, *see Diplodocus*
duck-billed dinosaur, *see Trachodon*
echinoderms, 6, 38, 39
Elasmosaurus, 54
Eocene Epoch, 26, 27, 28
Eohippus, 26, 27
exoskeleton, 6, 14, 20, 40, 41
fault, 6
Fenestella (bryozoa), 41
field book, 62, 63, 64
flint, 6
fish-lizard, *see* ichthyosaur
folding, 6, 7
Folsom point, 90
Foraminifers, 18, 43, 44, 70; *see also* protozoa
fossil bird, 54
fossil club, how to organize, 73
fossil-collecting equipment, 60–62, 74
fossil fish, 15, 18, 22, 23, 30, 92
fossil imprints, *see* casts and molds
fossil insects, *see* amber
fossil oysters, *see* pelecypods
fossil plants, 14, 19, 45–47, 77, 80
fossil sharks' teeth, 27, 28
fossil snails, *see* gastropods
gastropods, 7, 15, 23, 28, 29, 34, 67, 79

Gondwanaland, 10, 11
Goniatites, 36, 37
graptolites, 18, 20, 82
Gryphaea (oyster), 23, 24
Halysites catenulates (corals), 40
Harpoceras (ammonite), 25, 59
Hesperornis (bird), 55
Hildoceras bifrons (ammonoid), 36, 42
Holaster planus and *Holaster subglobosus* (heart urchins), 29
Holocene Epoch, 26
horned-lizard, *see Ceratosaurus*
Ice Age, 27, 58, 90
ichthyosaur, 22, 52, 53
igneous rock, 7
index-fossil, 7, 19, 20, 42, 43
Inoceramus (pelecypods), 59
Java Man, 57
Jeletzkya douglassae (squid), 81
jet, 46, 47
Jurassic Period, 22, 23, 37; *see also* dinosaurs and reptiles
labeling fossils, 66, 67
Lamellibranchs, *see* pelecypods
lamp shells, *see Terebratula*
Latimeria chalumnae (lobe-fish), 30
Leakey, Louis (Dr.), 57
Lepidodendron (tree), 45
Leptolepsis spattiformis (fish), 15
Lima gigantea (clam), 24
limestone, 7, 8, 18, 41, 60, 64
Lingulella davisi (brachiopod), 32
Lithostrotion (corals), 14
lobe-fish, *see* coelacanth
Lost Continent, *see* Gondwanaland
mammals, 7, 26, 27
mammals' ancestors, 22, 56, 57, 83
maps, geological (use of), 60, 62, 63, 64
Mesozoic Era, 12, 13, 21–25; *see also* dinosaurs
Micraster (heart urchin), 29
microfossils, 43, 44, 70, 71
mineral replacement, 8, 24, 25
Miocene Epoch, 26
Mississippian Period, 18, 19; *see also* coal
mold, 7, 25
mollusks, 7, 8, 31, 33–34
Mosasaurus, 54
mountain-building, 11, 51
museums, value of, 48, 49, 72, 73
nautiluses, 35, 84; *see also* cephalopods
Neanderthal Man, 57, 58
near-lizard, *see* plesiosaur
Neptunea contraria (whelk), 14, 15, 64, 65
Neuropteris (fern), 14
non-flying birds, 55
Nutcracker Men, *see Zinjanthropus*
Odontaspis (shark) teeth, 27
oil, 43, 44
Olduvai Gorge, 57
Olenus gibbosus (trilobite), 19
Oligocene Epoch, 26
Ophioderma (starfish), 59
Ophioderma tenuibrachiata (starfish), 39
Ordovician Period, 18
Oreopithecus (ape), 56
ostracoderms, 18, 92
ostracods, 5, 6
Oxytoma cygnipes (pelecypod), 33
Paleocene Epoch, 26, 27
Paleozoic Era, 12, 13, 17–20
Peking Man, 57
pelecypods, 8, 23, 24, 28, 33, 85; *see also* mollusks
Pennsylvanian Period, 19; *see also* coal
Pentacrinus (sea lily), 38
Permian Period, 19
permineralization, 8
petrifaction, 8
Pholidophorus, 22, 23
photography as part of paleontology, 68–71
phylum, 8; *see also* binominal system of classification
pithecanthropoids, 56

Pithecanthropus erectus, *see* Java Man
plate-bearing lizard, *see Stegosaurus*
plate-lizard, *see Elasmosaurus*
Pleistocene Epoch, 26, 27
plesiosaur, 22, 53
Pleurotomaria anglica (snail), 23, 67
Pliocene Epoch, 26
polyzoa, *see* bryozoa
Poriphera, *see* sponges
pre-Paleozoic fossils, 16, 17, 80
Primates, 27, 56, 57
Protocardia truncata (mollusk), 31, 33
protozoa, 8, 18, 43, 44, 70, 71; *see also* microfossils
Pseudopecten equivalvis (scallop), 25
Pteranodon, 55
pyrites and pyritization, 8; *see also* mineral replacement
Quaternary Period, 26, 67
Radiolaria, 70, 71; *see also* microfossils
reef-building animals; *see* corals, graptolites, and Stromatopora
repairing fossils, 66
reptiles, 8, 23
  sea-going, 22, 52–54; *see also* dinosaurs and Mesozoic Era
Rhynconella tetrahedra (brachiopod), 23
River-Meuse lizard, *see Mosasaurus*
rock outcrop, 8
rock stages, 13
rock systems, 13
  Cenozoic, 26
  Mesozoic, 21, 42
  Paleozoic, 17
sandstone, 9, 59, 60
sea lilies, 6, 18, 38, 39
sea urchins, 6, 39
  heart urchins, 22, 29; *see also* echinoderms
sedimentary rocks, 59, 60, 65
shale, 9, 24, 59, 60
Silurian Period, 18
Sinanthropus pekinensis, *see* Peking Man
spirifers, 18, 83; *see also* brachiopods
Spisula arcuata, 33
sponges, 8, 9
starfishes, 6, 39, 59
Stegosaurus, 22, 50
Stromatopora, 6, 18, 82
Sycostoma pyrus (snail), 28, 29
syncline, 9
Teallocaris loudonensis (shrimp), 73
Terebratula (brachiopod), 31, 32
Tertiary Period, 26
three-horned lizard, *see Triceratops*
thunder-lizard, *see Brontosaurus*
Trachodon, 81
Triassic Period, 21, 22; *see also* dinosaurs and reptiles
Triceratops, 49, 50
trilobites, 5, 9, 19, 20
Turricula rostrata (snail), 28
Tyrannosaurus, 49, 50
tyrant-lizard, *see Tyrannosaurus*
Volutaspina, 34
where to find fossils, 75–93
winged-lizard, *see Pteranodon*
Zinjanthropus, 57
zonal-fossil, *see* index-fossil

BOSTON PUBLIC LIBRARY
3 9999 01753 166 4

J
QE174
.3
.C3
1972 Cop2

Boston Public Library

HYDE PARK
BRANCH LIBRARY

The Date Due Card in the pocket indicates the date on or before which this book should be returned to the Library.

Please do not remove cards from this pocket.

Did you ever see a dinosaur?
Or a giant bird?
Or a cave man?

Then how do you know that they actually existed? How can scientists tell what they were and how they lived and how long ago they lived?

This book shows how scientists get their information: where they find the fossils that are evidence of the life on earth before the first man—how they identify them—and safely dig them out of their rockbed. You'll find out how specimens are cleaned and prepared, photographed, and studied, and the methods scientists use today to determine the age of their fossil finds!

Here are many photographs of different kinds of fossils—plant and animal life, too—and basic information about the rock layers that contain them.

The story of life on earth before man arrived is still a mystery. Here are some of the clues—what we deduce from them—and our methods of unearthing more.

HOW WE KNOW

What on Earth Happened Before Man Arrived

173
C1-63
all

STERLING PUBLISHING CO., INC. NEW YORK